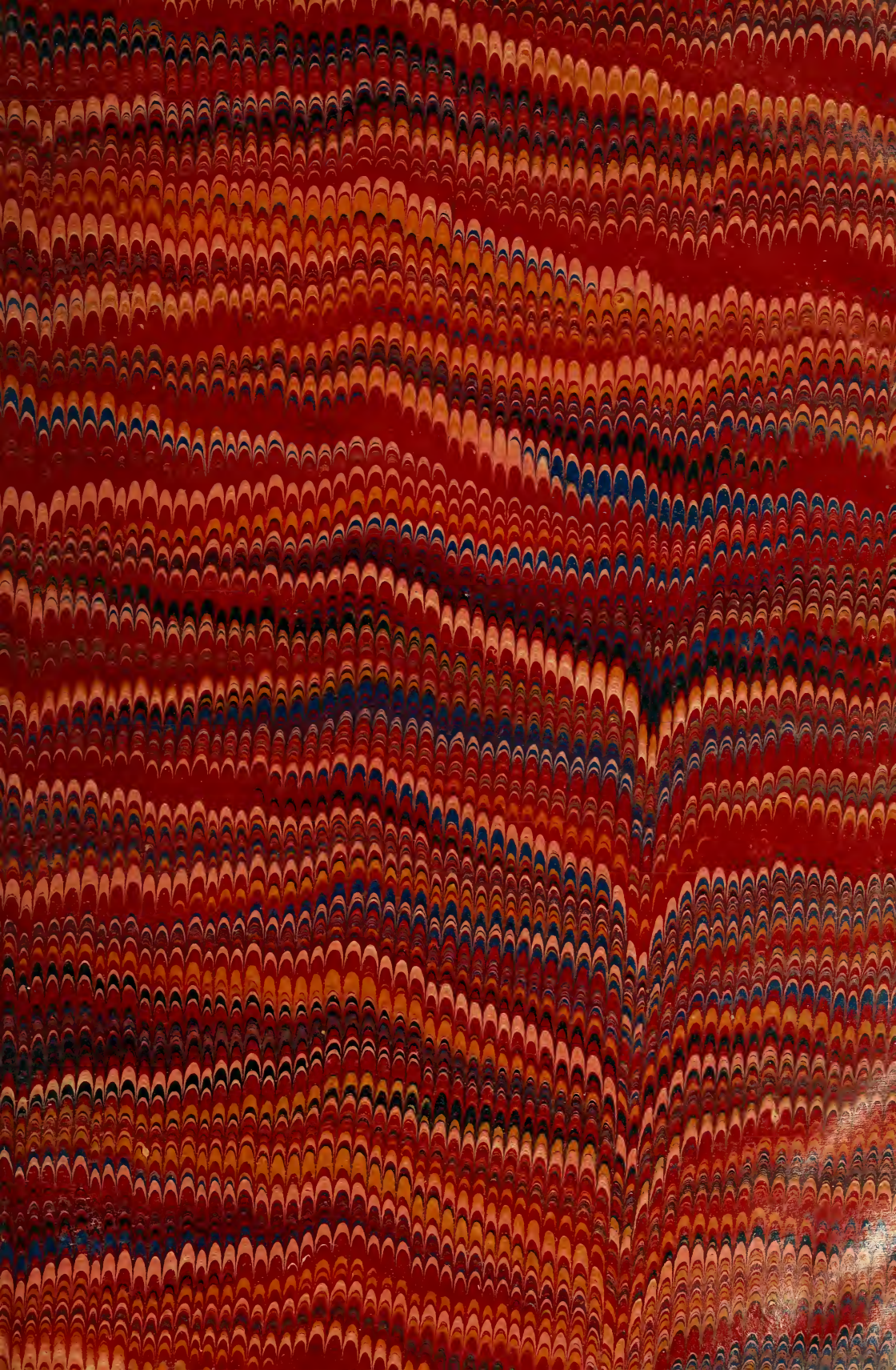




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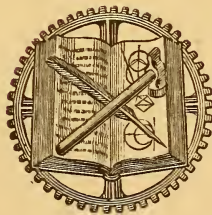
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PHYSICS AND HYDRAULICS OF THE MISSISSIPPI.

REPLY TO CERTAIN CRITICISMS MADE BY DR. HAGEN, DIRECTOR-  
GENERAL OF PUBLIC WORKS, PRUSSIA.

By BVT. MAJOR-GENERAL A. A. HUMPHREYS, Chief of Engineers, and  
BVT. BRIG.-GENERAL HENRY L. ABBOT, Major of Engineers.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

It is eminently proper that any book claiming to embody the results of extended and original investigation in an important branch of science should be subjected to very careful scrutiny before its conclusions are accepted. To afford every possible facility for such a study of the Report upon the Physics and Hydraulics of the Mississippi, its authors were careful to publish the data, in detail, so tabulated and illustrated by diagrams that any critic of moderate industry might reach the bed-rock upon which the conclusions were founded.

The work was translated into the principal modern languages of Europe, and has received marked attention from many eminent hydraulic engineers and scientists. The tone of criticism from this class of writers has generally been favorable, and has uniformly been courteous, with one distinguished exception—Dr. G. Hagen, Director General of Public Works in Prussia.

This gentleman, one of the most widely known hydraulicians of Germany, had published an extensive work on hydraulics in 1844; but it happened not to be ac-

cessible to the writers of The Physics and Hydraulics of the Mississippi, and, in the hurry of finishing the Report at the outbreak of the late civil war, no reference to it was made in their somewhat full historical resumé of the subject.

Mr. Heinr. Grebenau, Royal Bavarian Officer of Public Works, who, in 1867, published a translation of The Physics and Hydraulics of the Mississippi into German, with original notes and new material, made use of expressions of which the following are samples: "This theory, which makes an undoubted epoch in the history of hydraulics, dispels the darkness which even the latest hydraulicians such as Woltmann, Brünings, Eytelwein, Funk, and Hagen among the Germans, and Dubuat, D'Aubuisson, de Prony, Dupuit, and others among the French, have tried in vain to clear away." "While the older hydraulicians made known the results of their velocity measurements, which were often made with defective instruments, and thus rendered a service to science and practice, even now Hagen

gives neither the interesting observations made by him, nor, generally, any of his water measurements. Under these circumstances it is evident how the German learning and profoundness could be surpassed by the spirit of enterprise and perseverance of the Americans."

Dr. Hagen himself, referring to variations of velocity below the surface of flowing water, writes: "In this connection, the well known authors (of the Physics and Hydraulics of the Mississippi) propounded certain theories which found special favor with the translator of their work into German, and which in our country were so enthusiastically received that the danger of their general acceptance seemed imminent. I was, therefore, prompted to prove how little the observations upon which the theories were based are calculated to sustain them."

Under such circumstances, apparently slighted by us in the original work, and his own efforts contrasted unfavorably with ours by the German translator, himself a hydraulic engineer of eminence, the ordinary impulses of human nature might be expected to introduce some bitterness into the manner of presenting this "proof." We had, however, a right to expect that no *misrepresentation* should occur. Whether it did, or did not, will appear from the following facts.

Dr. Hagen, after describing the method employed by us for deducing the law governing the change in velocity from surface to bottom, brings the first specific charge in the following language. "The places on the river where the observations were made, or the different base lines were measured, are not sufficiently described. The reader is not informed whether the depths recorded extend over a greater length, or whether they are to be considered as limited depressions of the river bed only. The series of means given in the work refer twenty-seven times to the spot where the *prime base* was measured. This place is situated near Carrollton immediately below a very sharp bend of the Mississippi, as shown by a very small map on plate III, figure 2. The same map shows also that the *race-course base*, to which four series of means are referred, is situated a little farther down

the river on a straight part of its course. Of the three other places of observation the *Locks base*, the *Baton Rouge upper base*, and the *Baton Rouge lower base*, no information whatever is given. The width of the river at those places is nowhere indicated, although the distance of the buoy from the base is given in every case. From the small map alluded to, the Mississippi would appear to be about 2,200 feet wide at the first base, and about 2,500 feet at the second."

The facts are, that (in Appendix C) every possible detail respecting all these sections is presented, viz: a complete list of distances and corresponding soundings extending entirely across the river; the nature of the bottom; the high-water and low-water dimensions of cross-section, including the area, width, and wetted perimeter; and even the dates when the soundings were made. To render it certain that no reader should fail to discover every desired detail, his attention is especially invited on the small map to which Dr. Hagen refers, to Appendix B which gives the gauge reading on the days when the velocity measurements were made, and thus enables him to study changes in the curve in connection with the changes produced by the oscillation of the river. The *Locks base* is distinctly laid down on this map, although Dr. Hagen asserts that it is not. Plate II shows so clearly that Baton Rouge is on a straight part of the river, with no bend in the vicinity, that a small local map was considered unnecessary; but every detail respecting the sections there appears in the Appendices. Apparently Dr. Hagen was too much absorbed in searching for "proof" to give much attention to the text.

He continues as follows: "The velocities are given to within one ten-thousandth of a foot, or to within  $\frac{1}{10}$  of a line. Such exaggerations may possibly fascinate those readers who are not aware of all the circumstances connected therewith; but, in general, they only show that the investigations were carried on without regard to the degree of accuracy attainable."

To a practical investigator the true and very prosaic explanation of the reason why we published so many decimals

might be expected to suggest itself. Many of the quantities computed in the Report were so large that logarithmic tables reading to seven places, and giving results without interpolation in five figures, were uniformly employed. With the velocities now under consideration, this gives four decimal places—evidently more than are needful to represent the observations, but which can do no harm, except possibly to entrap a searcher for “proof.”

Dr. Hagen next proceeds to analyze very closely the table exhibiting the results of the subsurface velocity measurements; and he records several of his discoveries in a manner calculated to leave on the mind of the reader the impression that they have some significance injurious to the work. These suggested, but not specified, charges are best answered by a short statement of facts.

In general, no attempt was made to record the time of transit of a single float closer than to the nearest second; but many of these special sub-surface velocity observations were recorded with a stop-watch reading to quarter seconds. In combining several series of observations, decimals of seconds were of course always retained; but when only two floats had passed, this was sometimes neglected, the mean expressed in the nearest second being considered sufficiently exact. These simple facts give a full explanation of all Dr. Hagen's mysterious discoveries in arithmetic, except one which is thus stated. “Finally it is to be mentioned that in Group II, in 5 series, or in 36 sets of observations, the entire depth of the river was only 65 feet, while the velocities are reported as having been measured at a depth of 66 feet.”

The explanation of this paradox consists of two elements. First, in two of the five series, Dr. Hagen is in error when he asserts that the Report gives any velocity as “measured” at sixty-six feet below the surface. The figures are in “old style type,” and facing the first page of the report is a conspicuous note calling attention to the fact that this indicates interpolation. Second, Dr. Hagen places a forced construction on our language when he asserts that the entire depth of the river was only 65 feet. The Report states that it was

“about 70 feet,” which was actually the case. If Dr. Hagen had as closely inspected the figures in the column headed “depth” as he has done those in some of the others, he would have perceived that they are always expressed in multiples of 5 feet; and hence are evidently given as approximate. Any depth from  $62\frac{1}{2}$  to  $67\frac{1}{2}$  feet would appear as 65 feet, and Dr. Hagen has, therefore, no fair grounds for his criticism. As a matter of fact, however, upon referring to the original note books and diagrams used in the analysis, it is discovered that the depths printed as 65 feet in this table should have been 75 feet; and that the mistake occurred in transcribing the records for the press. The correct number was used in the analysis.

Having now driven in Dr. Hagen's skirmishers, we reach the main body of his attack. Without attempting to quote him in detail, it is believed that his views are fairly represented in the following summary. Dr. Hagen considers that the the actual accordance between our grand mean curve, representing 222 observations at each point, and a formula, which we deduced from it to represent the law of change below the surface, “transcends so much every conceivable degree of accuracy, that instead of confirming the result it is rather calculated to render it suspicious.” Here, then, a vital issue, the accuracy of our mathematical deductions from our data, is directly raised by Dr. Hagen, and he adduces two lines of argument to convince his readers that they are untrustworthy. The first is what he claims to be a statement of our method of reduction, with criticisms thereon; and the second is a theoretical computation, upon assumed data, showing what accordance should exist between measurements and theory, and that in this case the probable limit was exceeded.

It is not permitted to assume that a gentleman of Dr. Hagen's official position, even when engaged in the patriotic duty of preventing his country from being inundated by error, should deliberately misrepresent plain statements of an official document published by a foreign government. That he has done so, and in the grossest manner, is undeniable; and we therefore assume that eagerness for “proofs,” and want of familiarity

with the English language, combined to produce so surprising a result.

The apparent weight of Dr. Hagen's first line of argument is due to its confusing and misleading the reader as to what was actually done in reducing the observations. The shortest way to refute it, is to explain exactly the several steps; which can hardly be done in clearer language than that of the original Report.

"To counteract as far as possible any effect of change in velocity during the observations, the order of observing at different depths was constantly varied. Sometimes a series of observations consisted of one at each depth from surface to bottom, or bottom to surface. Sometimes many observations were made consecutively at each depth. Sometimes floats were started near the surface and near the bottom, and the distances between the planes were successively increased until the mid-depth was reached. In fine, every effort was made to avoid and eliminate error. The first steps toward deducing the law from the observations were therefore very simple.

"As floats are compelled to pass through nearly the same paths when starting from a fixed station, and are consequently unaffected by the change in velocity due to difference in distance from the banks, the principle was adopted of depending entirely upon the elaborated sets of observations from anchored boats. All the observations of each set being thus confined to nearly the same vertical plane, one great cause of error was practically eliminated. From the position of the boat, found by triangulation, the recorded gauge reading and the known depths of the different parts of the river section, the depth of water in each vertical plane was readily determined. The velocity of each float was deduced from the recorded seconds of transit past the base line, and a mean taken of all the observations at each depth for the true velocity at that depth."

It will be noticed that up to this point not one word has been said about any discussion of "single sets of observations" prior to this arithmetical grouping of the data. In truth no such subdivision of these observations into "single sets" was possible, as is ap-

parent when the reader remembers the continual variation in sequence of the observations at the different depths. There was no way to deduce primary curves of observation at any anchorage and date, except to take a "mean of all the observations at each depth for the true velocity at that depth."

But Dr. Hagen conveys to the reader a totally different idea, by transposing a subsequent process of the reduction backward, and pretending that it was applied to imaginary "single sets." He thus represents that the primary figures in the text are not the simple means of observation, but figures derived by an arbitrary process from such original sets; and, hence, that they are vitiated by our preconceived ideas as to what the curve ought to be. Any such view is absolutely false, and is warranted by no line or letter of the Report; and yet Dr. Hagen's whole first argument is based upon it, as is seen by the following extract from his paper:

"After the conviction had been arrived at, that below the surface the velocities first increase with the depth and then decrease until the bottom is reached, every single set of observations was graphically represented, and this was done on so large a scale as to admit of the reading of one thousandth of a foot of velocity. The drawing, therefore, was far more accurate than the observations which were represented by it. Between the points thus obtained, a curve was drawn which satisfied the conditions mentioned above, and which at the same time exhibited the closest possible connection with the observations.

"The reader cannot repeat this operation for himself, since only one set of observations is given which is entirely free from any combinations; and this particular set can indeed be made to furnish approximately a curve of the character mentioned above. All the other sets, however, appear in combinations, and contain the means of these combinations only."

Continuing this misrepresentation, Dr. Hagen selects the three worst of these *primary*, not *combined* curves, and concludes: "These combinations show so great anomalies as to impress us with the arbitrary character of their graphical representation. If the law of the curve

had been known previously, then of course its elements might have been computed by the method of least squares; but in that case it might also have appeared that some other curve, or even a straight line, was the more probable expression of the law than the curve originally introduced."

He does not state, what is the fact, that we decided that the number of observations from which these primary curves were derived was not sufficient to cancel abnormal influences; and that we made no attempt to discuss them but concluded, "that some combination of curves was necessary to reconcile discrepancies of observation."

How the combination was effected by us is explained by the following extract: "The first method adopted was to combine all curves of observation where neither the depth of water nor the velocity of the river varied materially. This was done by taking a mean of the velocities of all the floats at each depth, each set of observations thus receiving a weight proportioned to its number of observations at each point. When observations were wanting at any depth, careful interpolations were made from the plotted curve. The resulting mean curves are exhibited on Plate XI, Figures 1, 3, 10, 2, 4, 9; the numbers being shown in the following tables."

These tables, six in number, represent on the horizontal lines the original primary means obtained arithmetically from the several floats. When observations at any depth are wanting, the interpolations adopted by the authors are given, printed in "old style" figures, so that any critic can revise them. The foot line of each table gives the arithmetical mean of the primary means, and represents the combined curve for that particular depth and velocity.

We now come to our final process, which Dr. Hagen has misrepresented by pretending that it was applied to his imaginary "single sets." It will hardly be denied that the process was legitimate and necessary; and every facility for repeating it in detail was extended to the critic by the tables published in the Report.

"These curves," as the Report states, "at once indicate the existence of law, although the discrepancies are too great

to permit the deduction of any algebraic expression for it. It is evident, however, that the velocity differs very little at different depths; that it at first increases as the depth is increased; that the point of maximum velocity is found at a very variable depth below the surface; and that the degree of curvature of the curve varies with the stage of the river.

"It is manifest that some further combination is necessary in order to eliminate the effect of disturbing causes. Since the absolute depths differ, this can only be done by combining the velocities at proportional depths, leaving the correctness of this principle of combination to be eventually tested by the application to each individual curve of the law thus deduced. The method adopted for this combination was to plot the mean curves on a scale so distorted that thousandths of a foot of velocity were readily distinguished." In other words, the arithmetical means of the observed velocities were plotted at their respective depths, and connected by lines which, it will be found, in nearly every instance were *right lines*—the only exceptions being when a decided general change in curvature above and below suggested a slightly curved line. "The entire depth was then divided into ten equal parts. Horizontal lines were drawn, and the velocities at their points of cutting the curves noted. These numbers were the most correct interpolations that could be made for the velocity at each *tenth of depth*, and they were next combined in the ratio of the number of observations. The points inclosed by circles in Fig. 16, Plate XI, exhibit the mean points thus determined, the grand mean of all the observations from anchored boats. They are plotted from the first column of the next table. Each point is fixed by 222 observations; enough, as the result proves, to eliminate irregularities and to reveal the law governing the transmission of resistance through the fluid."

Having thus shown that Dr. Hagen's first line of argument rests solely upon his misrepresentations of what we did, and is not applicable to what we actually did, we proceed to notice his second argument. He says: "The question remains to be answered, How is the demonstrated agreement of the new law with the observations to be accounted for?"

That the errors of observation should have adjusted themselves so completely by mere accident cannot well be assumed, since the probability of such a self-adjustment is altogether too small."

He then proceeds, upon assumed data, to compute what this probability is, and arrives at the conclusion that it is one in thirty billions. He then proceeds:

"This definite form of the phenomenon, however, *has* occurred, and from the small probability of its causation by *other* agencies, we may infer the *probability* of its actual causes. Such might, for instance, be the intentional selection of some observations in preference to others which, not agreeing with the preconceived law, were rejected as inaccurate or erroneous. This cause is in itself by no means improbable. Persons who are not accustomed to scientific exactness sometimes believe that such a proceeding is admissible and entirely correct. In the present case the measurements were of an official character and were carried on under a kind of formal control; it might therefore not have been an easy matter to reject observations as erroneous which, when made, were not doubted.

\* \* \* \* \*

"There is, however, another and indeed a very natural explanation of this agreement. Let the reader try to establish a graphical connection between the series given in the above drawings and curves of such character as described above, and he will see at once that this is quite an arbitrary process. The most various curves are equally admissible; their course may be arbitrarily changed either in whole or in detail without the introduction of an error. Thus an easy method was obtained to establish, first a connection between the observations and any curve which had been previously selected, and then to reduce quite arbitrarily the errors still remaining. There would have been no difficulty in drawing the curves so as to make the means agree with the computation to within seven decimals.

"The young student of hydraulics is sometimes compelled to accept certain theorems as true and proven which, to say the least, are still doubtful; but he has as yet never been expected to re-

ceive devoutly a demonstration like this, and to regard it as a progress of science."

An argument of this nature is so extraordinary, that it is not easy to reply to it with dignified composure. We will simply say that there was no "intentional selection of some observations in preference to others." Every record was admitted and published. Also that there was no use whatever of the arbitrary process which Dr. Hagen has imagined, and, without any grounds for so doing, has asserted that we did use. No mathematician will dispute that in combining such curves interpolation cannot be avoided where points are missing. To guard against any possible misconception, we indicated in every instance such interpolations in the tables by "old style" figures. Not a single interpolation was made which is not thus submitted for the revision of the critic. Out of a total of 369 points of the primary curves, only fifty are interpolations; and the vast majority of these occur in sensibly straight portions where a simple mean can be and was used. If Dr. Hagen can point out any sensible change which can be made in our grand mean curve of observations by correcting errors in these interpolations, he will succeed in reducing the "incredible" accordance between it and our theory. If not, he must revise his own computations as to probable error. These interpolations, all plainly indicated in the text, are the only points open to discussion; everything else is direct measurement.

As to publishing the observations in the minute detail which Dr. Hagen regards as essential, it need only be remarked that the cost would have been quite beyond the amount of funds available. To have done so for this single subject of change of velocity below the surface, would have added many pages of figures. The corresponding observations at other points, and those for the change of velocity from shore to shore, should upon the same grounds be published; and so should also the diagrams showing the positions and paths of floats, and a variety of other details which, taken together, would make at least a quarto volume containing many hundreds of pages. And to what purpose

would this expense have been incurred, when we find that certain important details which have been given in the fullest manner in the Report, are asserted by Dr. Hagen not to have been given at all.

In truth, if Dr. Hagen had attempted to impartially weigh, instead of to attack, our conclusions, he would have seen that our theory suggests why it may be expected that a combination of many observations should closely represent the normal form of the curve. The discrepancies usually exhibited by single measurements are largely due to oscillations of the horizontal axis of the parabola, which repetition soon eliminates. It is a fact, now well known, that Boileau, Bazin, Grebenau, Ellis, and other observers have obtained mean curves very closely agreeing with our parabolic law. Indeed, Grebenau found that still older observations accorded with it so well that he wrote: "It is remarkable that the law of decrease which is obvious in all these earlier experiments could have remained so long unknown. If, however, it be remembered that Brinings only worked with logarithms, and made no attempt to represent former measurements, or his own observations, graphically with compass and scale, it will be understood how the discovery of the law was so difficult."

We cannot better close our remarks upon Dr. Hagen's attack upon this part of our work, than by quoting from a paper published in 1875 by M. Bazin, a distinguished Engineer of the Ponts et Chaussées, whose labors and writings place him confessedly in the foremost rank of living hydraulic engineers. He writes:

"The distribution of velocity in flowing water has been made the subject of numerous experiments, which are far from being accordant even for the simplest case—that of a canal of indefinite width, where the effect of the sides can be neglected. When a large river is dealt with, these experiments present considerable practical difficulties, and the eminently variable and capricious nature of the phenomena, in which many secondary influences mask the true laws, add to these difficulties. Nevertheless, hydraulicians now generally admit that the velocity upon a single vertical, varies

as the ordinates of a parabola. The maximum velocity is sometimes at the surface, and sometimes below, although no one has as yet succeeded in giving a satisfactory explanation of the causes which induce its changes in position. According to this parabolic law the velocity at any given point upon a vertical, may be deduced from its depth  $d$  below the surface, by the very simple formula:

$$v = V - m \left( \frac{d-d_1}{D} \right)^2$$

This is our formula. It was first announced in the *Physics and Hydraulics of the Mississippi*; and against it was directed the attack to which we have just replied, and which was published ten years ago. If Dr. Hagen and his admirers had not recently quoted this old attack as proving that our data were suspicious, and "probably altered in part to establish the theory proposed," this reply would not have been deemed necessary. At its date, and indeed until very recently, it failed to come to our notice.

Taking leave of the subject of the change of velocity below the surface, we now proceed to consider very briefly Dr. Hagen's strictures upon our formula for the mean velocity of a flowing river, as he has presented them in his *Investigations on the Uniform Motion of Water*, published in 1876.

He admits the great value of our 19 observations for discharge, slope, etc.; asserts that the true method of deriving a formula from them is the method of least squares; assumes the general expression for the velocity in terms of the slope and mean radius to be  $v = As^{2.7}r^y$ ; and decides that the value of his constants from our observations should be:

$$A = 7.645 \quad x = 0.2271 \quad y = 0.51.$$

Applying this formula to the observations from which it was deduced, he finds the sum of the squares of the residuals to be 0.6858. He then remarks:

"Humphreys derived another analytical expression from his observations which we ought not to omit giving to the reader, since immediately after the publication of the translation of the American work, the attention of the German engineers was directed to the superiority of this new theory over all the older ones."

He proceeds to misquote our formula in so gross a manner as to show that the proofs of his paper were corrected with culpable negligence. But even this treatment is better than we received in his former article, in which he quoted instead of our formula an approximate expression the application of which we had carefully restricted, and applied to it criticism that derived its whole weight from this substitution. He continues:

"By this most inconvenient formula Humphreys himself computed the velocities; and the differences between these results and the observations are given in the last column of a table on page 317 of his work. The sum of the squares for these 19 observations amounts to 1.5296. This is  $2\frac{1}{2}$  times as large as that given above, while the probable error amounts to 0.21 feet; hence it seems superfluous to recur to this theory again."

In reply to these views of Dr. Hagen we will say, that, in our opinion, he has adopted an arbitrary and mechanical method of discussing the observations, which is open to criticism. The object proposed in making these measurements was to discover from them the natural laws which govern flowing water, and to deduce a formula which would truly represent these laws, and not one which would give the smallest probable error when applied to the limited data available. To do this, it is not admissible to arbitrarily assume the form of the equation. This must embody all the known laws affecting the variables. The observations, when few in number, should determine the numerical values of the constants, *not so as to make the sum of the squares of the residual errors a minimum, but so as to fulfil the most probable conditions suggested by careful mental study.* In such an investigation, the graphic method possesses incontestable advantages over that of least squares; and we therefore gave it the preference.

Whether Dr. Hagen or ourselves be right in these opposite views as to the proper manner of treating the problem mathematically, admits of a direct test.

It will not be denied that the best proof of merit in a formula of this nature, is the correct prediction of results afforded by new measurements not available in deducing its constants. Our formula was based upon 30 standard

measurements; of which 19 were our own, and 11 had been published in such detail as to warrant a belief in their accuracy. There are now available in addition, 49 similar observations published by Darcy and Bazin; 15 published by Grebenau; and 4 made upon the upper Mississippi by General Warren and Mr. Clarke. The whole will be found in Johnson's Cyclopædia (article Rivers, Hydraulics of). Out of these 68 new observations which were not available when our formula was framed, no less than 42 largely exceed the limits in respect to cross-section and slope within which we restricted its use. The test of its general applicability to natural channels which they afford, is therefore exceedingly severe. Nevertheless, the mean discrepancy for the 98 observations is only 9 per cent,—much less than for any other single formula which has ever been proposed, and 1 per cent. less than Dr. Hagen thinks it reasonable to expect from such a formula.

All these observations, except probably the last four, were available and known to Dr. Hagen when deducing his latest formula of 1876. In this work he proceeded upon his general method indicated above; abandoned the attempt to frame a single formula; and finally adopted two radically different expressions, one applicable when the mean radius is less than 1.5 English feet, and the other when it is greater than this quantity. These expressions in English feet are respectively:

$$\text{when } r < 1.5 \quad V = 4.9 \, r^{\frac{1}{2}} \sqrt{s}$$

$$r > 1.5 \quad V = 6 \sqrt{r^{\frac{1}{2}}} \sqrt{s}$$

When this double formula is applied to the 98 standard observations, the mean discrepancy is 12 per cent.

In fine, then, from 30 observations in 1860 we were able by our method to frame a general river formula which gives a mean discrepancy for these 98 standard observations of only 9 per cent; while Dr. Hagen in 1876, by his method, is only able to reduce his discrepancies to 12 per cent.—and that, by resorting to the expedient of using a double formula. Comment seems to be superfluous, except perhaps to suggest that Dr. Hagen's polite assumption that the familiar method of least squares "was probably unknown" to us is not necessary

to account for our preferring our own method of analysis.

In conclusion, we may say that the investigations of the Mississippi Survey were conducted with the sole desire to develop truth. The contributions to the science of hydraulics were not the end sought; but rather the means by which practical conclusions involving immense financial interests might safely be reached. The first use of the discoveries, long before they were published to the world, was made in discussing the prob-

lem of protecting the alluvial region of the Mississippi against overflow. As our professional reputations were at stake in arriving at correct conclusions in this matter, which, sooner or later, will surely be put to practical proof, we gave every step of our analysis a scrutiny more severe and thorough than it probably will again receive. At any rate, the critic may rest assured, at the outset, that we committed no errors so gross and absurd as those which Dr. Hagen has imagined.

## THE "GEOMETRY OF POSITION" APPLIED TO SURVEYING.

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### I.

#### INTRODUCTORY.

I. I PURPOSE to set forth as briefly as possible, a few results obtained from the application of the "*Geometry of Position*" to the solution of such problems in surveying as are of every-day occurrence, believing that the results thus obtained will not prove altogether uninteresting or unprofitable. As the *Geometry of Position*, however, is a branch of mathematics, scarcely known even by name in this country, some statement of its peculiar character and chief merit seems quite in place by way of preface.

That such a statement can be justified on such grounds, is, to say the least, a matter both of regret and surprise. Of regret, that so simple, so beautiful, so eminently useful a branch of mathematics has been suffered to remain so long unheeded. Of surprise, that in spite of the relation in which Geometry stands to all other branches of mathematics, a most important advance in Geometry is quite unknown; that in spite of the efforts so persistently made to simplify and reduce all mathematical processes, a most effective agent for this purpose is yet unused. Nothing perhaps is more characteristic of the present state of the mathematical sciences than the simplicity of their solutions. It seems, indeed, as if that inventive spirit which in the industrial arts has

led to the production of numberless labor-saving machines, has invaded even mathematics, and led to the production of all manner of labor-saving processes of solving long and difficult problems, till now it is possible to solve graphically, with the ruler and pencil, any problem from a proposition in the rule of three, to the determination of strains in the parts of the most complicated engineering structure. In the industrial arts such labor-saving machines are said to be the direct result of a lack of skilled manual laborers: perhaps in mathematics such labor-saving processes may, to some extent, be the direct result of a lack of skilled intellectual laborers. However this may be, the Geometry of Position, though capable of accomplishing much in the above mentioned respect, has as yet been turned to no use. Indeed it is taught *nowhere* out of the Polytechnic schools of Germany, while a text-book on the subject in English remains to be written.

As a branch of Geometry it is peculiar in all respects. If the story that has come down to us from the time of Thales is deserving of any credit, the science of Geometry arose from the efforts of the Egyptian priests to restore the landmarks and boundaries washed away by the yearly inundations of the Nile, and

to determine the areas covered by the fertilizing waters; a statement which the Greek name Geometry—"Land-measuring" tends not a little to confirm. But whatever may have been its origin this much is certain, that Geometry as a science first appeared in the valley of the Nile, and that among the Egyptians it held very much the same place surveying holds with the nations of to-day. At the very beginning, therefore, Geometry became associated with the idea of measure, and so firmly has this been clung to, that ever since, in whatever form the science has appeared, whether as Trigonometry or Analytical Geometry, magnitude or quantity has formed the basis. It is now universally conceded that measure is not an essential element of Geometry; and that while there is a *Geometry of Magnitude* or *Quantity* there is also a *Geometry of Figure*. Almost within our own day the science has been divided into the "*Old Geometry*" or "*Geometry of Measure*" and "*Modern Geometry*" or "*Geometry of Figure*" under which is to be placed the "*Geometry of Position*."

## II. THE GEOMETRY OF POSITION

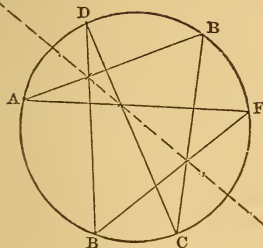
differs essentially from the Old Geometry or Geometry of Measure in three particulars; in the simplicity and paucity of its elements; in the total absence of the idea of measure and all metrical relations; and in the great generality and comprehensiveness of its principles and problems.

The fundamental elements of the ancient geometry are, the point, the line, the plane, the angle, the circle, solid bodies, surfaces of revolution and the long array of triangles, rectangles and polygons. The fundamental elements of the *Geometry of Position* are the point and line. The most marked peculiarity however, is the total absence of all metrical relations. In the old geometry the metrical relations of the parts of the figure are never for a moment lost sight of. It is the length of some line or the bisection of some angle, the equality or similarity of some figures, the value of the square of some side that is to be demonstrated. It is a proposition on the intersection of medial lines, on the measure of inscribed angles; on the ratio of homologous sides; on areas, on volumes,

on circumferences, on perimeters. The Geometry of Position, on the other hand, takes no account of measure either angular or lineal. In none of its problems is there to be found any mention of perpendicular or oblique lines, of angles, of areas, or of volumes. It has nothing to do with triangles whether right or oblique, isosceles or scalene; nothing to do with rectangles or parallelograms, or with regular or irregular polygons. No line is ever bisected; no angle is ever read. The student therefore, who, familiar with the principles and problems of the Old Geometry, enters on the study of the Geometry of Position, finds himself, so to say, at the beginning of a new science. Theorems and axioms, corollaries and scholiums, which he has long looked on as the very frame work of geometry, are utterly abandoned, and, without considering the length of a single line or the measure of a single angle, he enters on the solution of problems of the utmost generality and comprehensiveness. In the Old Geometry of measure the majority of propositions are necessarily limited in the scope of their application, the conditions on which their demonstration depends, are particular rather than general. Change the length or inclination of a line, alter the measure of a single angle, and the proposition falls to the ground. Propositions that are true of right angled triangles are not true of oblique angled triangles. Propositions true of equilateral are not true of scalene triangles. In the *Geometry of Position* whatever is true of *one* figure of three sides is equally true of *every* figure of three sides, no matter how long or short the sides may be, or how various their inclination to each other. In the Geometry of Measure again, what is true of the circle is not necessarily true of the ellipse, the hyperbola, and the parabola, but such is the comprehensiveness of the Geometry of Position, that *every* proposition true for the circle is true for the ellipse, the parabola, the hyperbola, in short, for every curve of the second order. The length of the radius, the position of the foci, the length of axis is never for a moment considered. It is the *position* of lines, not measure, that determines all things. Thus it is one of the propositions of the geometry of position that if any six points be

taken *anywhere* in the circumference of a circle and joined by consecutive straight lines in *any order whatever*, then will the three points of intersection of the three pairs of opposite lines lie in one and the same right line; an illustration of this is given in figure 1. The points

Fig. 1.



are there taken in the order  $ABCDEF$ , and joined by the six consecutive lines,  $AB, BC, CD, DE, EF, FA$ ; the three pairs of opposite lines intersecting in the three points  $a, b, c$ , which lie in the right line  $ac$ . By opposite sides is meant every *first* and *fourth* line taken consecutively. Thus beginning with the line  $AB$ , the *fourth* line in consecutive order is  $DE$ , therefore  $AB$  and  $DE$  are opposite lines; so are  $BC$  and  $EF$ ; so are  $FA$  and  $DC$ . Now this proposition is true not only for *any* six points taken *anywhere* on the circumference of a circle and joined in *any order whatever* by consecutive lines, but for *any* six points on an ellipse, a parabola, an hyperbola, or in fine for *any* six points on *any* curve of the second order. The proposition is therefore general and comprehensive to the last degree. Yet it takes no account whatever of measure or metrical relations.

Two other propositions may perhaps afford a yet clearer idea of the character of the propositions of the *Geometry of Position*. It is, however, but just to state that they have not been *especially* selected for this purpose, but are here introduced mainly because they are to be applied later to the solution of problems in surveying. The first of these is to this effect. If  $A, B, C$ , be *any* three points in *any* three concurrent lines, and  $A', B', C'$ , any three other points in the same lines, and  $a, b, c$ , the three inter-

sections of the three pairs of connectors  $BC$  and  $B'C'$ ;  $CA$  and  $C'A'$ ;  $AB$  and  $A'B'$ ; then are the points  $a, b, c$ , in the same right line. The proposition is extremely general, the points may be taken anywhere in any three concurrent lines, and however great or small the angles which the lines make with each other, the proposition is invariably true. It is apparent from the figure that the statement of the proposition may be varied as follows: If any two right lined figures of three sides each, as  $ABC$  and  $A'B'C'$  (Fig. 2), be so placed that the connectors of each pair of corresponding points  $A$  and  $A'$ ;  $B$  and  $B'$ ;  $C$  and  $C'$  meet in a point  $P$ ; then the three points  $a, b$ , and  $c$  of intersection of the three pairs of corresponding sides  $BC$  and  $B'C'$ ;  $AC$  and  $A'C'$ ;  $BA$  and  $B'A'$  are three points in a right line. No account is taken of the distance these figures are apart; no account is taken of the length of the sides, nor of the angles they make with each other. Yet the proposition is invariably true for all sizes and shapes of figures having three right-line sides when so placed that the lines joining each pair of corresponding points pass through a common point.

The second proposition is this: If  $A, B, C$  and  $D$  be any four points of intersection of *any* two pairs of concurrent lines and the points of concurrence  $a$  and  $c$ , of these lines be joined by the line  $ac$ , then will the connectors  $AC$  and  $BD$  of the two pairs of opposite points  $A$  and  $C, B$  and  $D$ , meet the line  $ac$  in two points  $b$  and  $d$  such that if either one with the two points  $a$  and  $c$  remain fixed, the other will also remain fixed for all possible positions of the points  $A, B, C$  and  $D$ . Or, to state it differently, if  $ABCD$  be any right lined figure of four sides, and the two pairs of opposite sides  $AB$  and  $CD, BC$  and  $AD$  be produced till they meet, then will the two diagonals  $AC$  and  $BD$  when produced cut the line  $ac$  in two points  $b$  and  $d$ , such that if either one with the two  $a$  and  $c$  remain fixed, the other will also remain fixed for all possible positions of the figure  $ABCD$ . This is illustrated by the figures on the right and left of  $ABCD$ . Here again no account is taken of measure. The length of the sides, the distance of the figure from the line  $ab$ , the measure of the angles has nothing to do

with the proposition. So long as the *position* of the sides is such, that each pair of opposite sides intersect when produced, the proposition is *invariably true*.

### III. ANHARMONIC RATIO.

This singular result should seem to indicate the existence of some fixed relation between the four points  $a, b, c, d$ , a

relation which on examination is found to be of the very highest value in the application of the Geometry of Position to practical uses. The four points  $a, b, c$  and  $d$ , will, it is evident, always lie in a right line, and possess relations and properties that may be briefly summed up as follows: The four points are four anharmonic points, constitute an anhar-

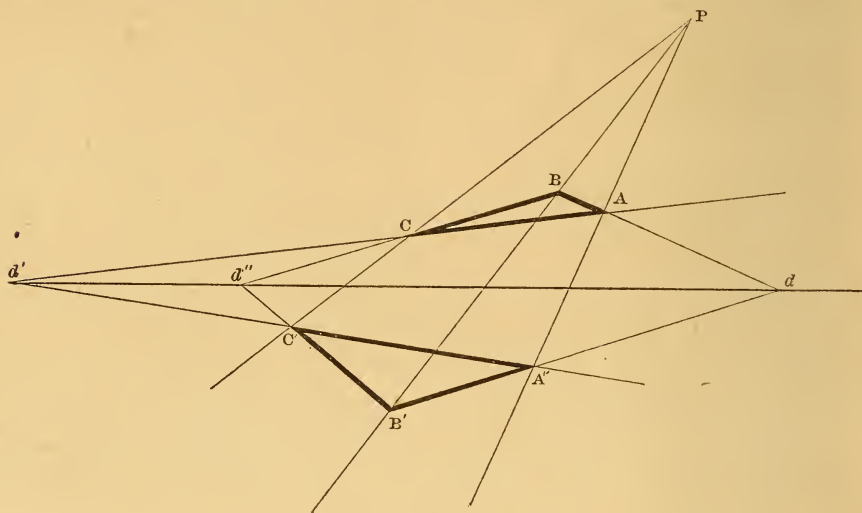


Fig. 2.

monic range, cut the line anharmonically, have an anharmonic ratio, and taken in pairs are the anharmonic conjugates of each other, that is to say  $a$  and  $c$  are anharmonic conjugates, as are also  $b$  and  $d$ .

By anharmonic ratio is meant simply this. If any line as  $ac$ , Fig. 3, be cut at any two points  $b$  and  $d$ , the line is cut into six non-adjacent segments, or segments having no end in common. These are  $ac$  and  $bd$ ;  $ab$  and  $cd$ ;  $ad$  and  $bc$ . Now, if any two pairs of non-adjacent segments be taken the ratio of ratios of these two pairs is the *anharmonic* ratio of the section of the line. Thus, if the sections taken be  $ac$  and  $bd$ ;  $bc$  and  $ad$ , then the ratio of ratios is

$$\frac{\frac{ca}{cb}}{\frac{da}{db}} \dots \dots \dots (1)$$

Or again to express it more simply, if  $a, b, c$  and  $d$  be any four points on a right line, and these points be taken in

any order whatever, the ratio of the first and second to the third, divided by the ratio of the first and second to the fourth is the anharmonic ratio of the four points. So that the four points being taken in the order  $a, b, c, d$ , the anharmonic ratio is by the above definition

$$\frac{\frac{ac}{bc}}{\frac{ad}{bd}} \dots \dots \dots (2)$$

an equation precisely similar to equation (1). This ratio for the sake of brevity is written  $[abcd]$ , the order of the letters indicating the order in which the points are taken.

As these points may be taken in *any* order, and as the four letters representing them may be written in twenty-four different combinations, it should seem that there should be twenty-four different anharmonic ratios for each range of four points. When, however, the anharmonic ratio for each of these twenty-four combinations is written out, it ap-

pears that there are but six anharmonic ratios differing in value, and that each one of these six may be written in four different ways *without altering its value*. Thus, taking the points in the order  $a, b, c, d$ , we have

$$[abcd] = \frac{ca}{cb} : \frac{da}{db} = \frac{ca \cdot db}{cb \cdot da}$$

$$[badc] = \frac{bd}{ad} : \frac{bc}{ac} = \frac{bd \cdot ac}{ad \cdot bc}$$

$$[cdab] = \frac{ca}{da} : \frac{cb}{db} = \frac{ca \cdot db}{da \cdot cb}$$

$$[dcba] = \frac{db}{cb} : \frac{da}{ca} = \frac{db \cdot ca}{cb \cdot da}$$

The anharmonic ratio  $\frac{ca}{cb} : \frac{da}{db}$  may there-

fore be written in either of the four ways  $[abcd]$ ,  $[badc]$ ,  $[cdab]$  or  $[dcba]$ . So may each of the five other ratios be written in four ways, without a change of value; the six different ratios and the four different ways of writing each, account-

ing for the twenty-four combinations of the points  $a, b, c, d$ .

When the value of the anharmonic ratio is unity, the points are said to be harmonic points and the ratio an *harmonic ratio*.

In connection with this matter of anharmonic and harmonic ratio it is to be remarked, that the truth of this statement that the Geometry of Position takes no account of metrical relations, is not at all impugned by the fact that these *ratios* are based on the measure of the segments. They are, so to say, afterthoughts. The propositions of the Geometry of Position are wholly independent of anharmonic and harmonic ratios, which are, indeed, results derived from the Geometry of Position. In many instances, however, where a practical application of this Geometry is made, the necessity of obtaining the measure of lines arises, and then is it that these ratios are found invaluable. Such is the case when applied to the solution of

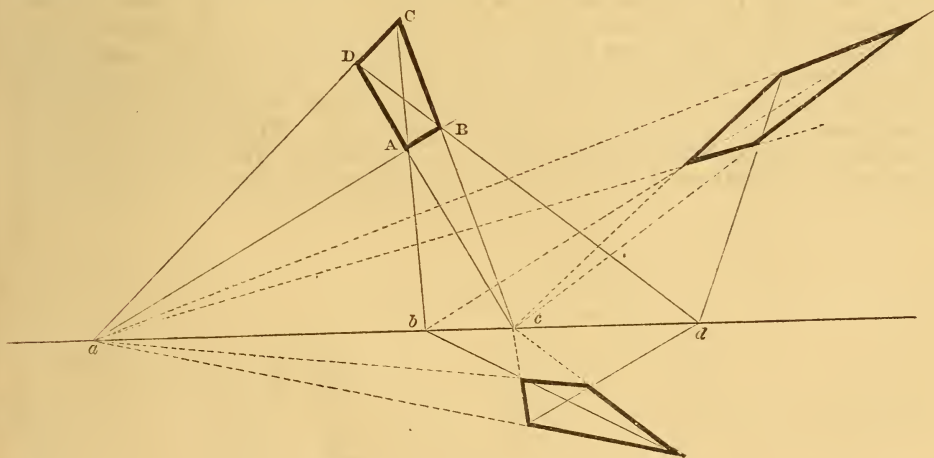


Fig. 3

problems in surveying, and on this account it has been judged best to briefly introduce the matter of anharmonic ratio before taking up the matter of surveying by the Geometry of Position.

#### IV. SURVEYING BY THE GEOMETRY OF POSITION.

We shall begin with the proposition illustrated in Fig. 3. The problems in Engineering Field-work, to the solution of which this proposition is applicable, fall under one of three classes.

- 1° To prolong a line through or across some obstruction, as a house, a marsh or pond.
- 2° To obtain the measure of an inaccessible or immeasurable distance.
- 3° To locate and find the distance to a remote point.

#### 1° TO PROLONG A LINE THROUGH AN INVISIBLE POINT ON THE LINE.

The problems in this class are undoubtedly the most frequently met with

of all, and the methods of solving them now in use, by perpendiculars, by equilateral triangles, by similar triangles, and by triangulation are so familiar that it is unnecessary to do more than recall the fact that they all depend on angular and chain measurement, and that the character of the ground surrounding the obstacle to be passed will in general determine which of the three is to be used.

The Geometry of Position, on the other hand, affords two methods of passing round an obstruction, each of which is based on the proposition regarding the right line figure of four sides; is wholly independent of angular and chain measurement, and is applicable in *all* cases, whatever may be the nature of the obstruction or the physical character of the ground. Suppose, for illustration, that in locating a tangent on a railroad, represented by the line AX in Fig. 4, some obstruction as a house is met with at O. Now, by simply reversing the third proposition, which is illustrated in Fig. 3, it becomes applicable to the present case. For it is evident that if from any two points *a* and *b*, on a right line, two pairs of lines be drawn in such wise as to form by their intersection a figure ABCD, the two diagonals AC and DB will cut the line

*ab* in two points *c* and *d*. To apply this to the solution of the problem in hand it is merely necessary so to arrange that the three points *a*, *c* and *b* shall be on the line to be staked out and all three on the *same* side of the obstruction while the point *d* is on the other side of the obstacle. The first condition is easily satisfied since the points *a*, *b*, *c* may be taken *anywhere* on the line staked out before reaching the obstruction. All turns, therefore, on the determination of the point *d* at which the diagonal DB cuts *ab* produced, and this point may be found by either of two methods.

#### FIRST METHOD.

It will be remembered in connection with the proposition that if any three of the points remain fixed, the fourth point will also remain fixed for *all* positions of the figure ABCD as illustrated in Fig. 3. That is to say, if *a*, *b*, *c* are fixed points, the diagonal DB will *always*, for all positions of ABCD, pass through the same fixed point *d*. In order to find *d* on the ground it is necessary merely to lay out two figures ABCD and A'B'C'D', and find the intersection of the two diagonals CD and C'D'. This will be a point in *ab* produced. The simplest method of doing this is illustrated in Fig. 4, and

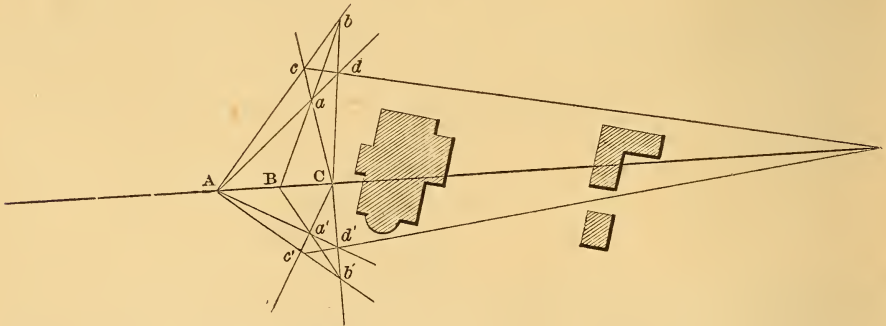


Fig. 4

is performed as follows. Select *any* three points as A, B and C in the line previously located; set the instrument at B, and facing the obstacle turn the telescope off to the right of the line and locate two points, *a*, and *b*, in the line of sight such that from each of them a sight can be had past the obstruction. Now turn the telescope to the *left* of the line and in the same way locate *a'* and *b'* in

the line of sight. Move to A and sight to *b* and locate a part of *Ab* near where it seems to cross a line joining *aC*. Then sight to *a* and locate a part of *Aa* near where it seems to cross a line joining *bC*. Next sight to *b'* and *a'* repeating the operation just described. This has all been done without moving from A. Now set the instrument at C, sight to *a* and locate *c*; also sight to *b* and locate





one half the distance AB, then CD is equal to AC, a fact worth remembering when the first method of prolonging the line is used, as in that case the points A, B and C, are taken at pleasure, and can therefore be so taken that  $BC = \frac{1}{2}AB$ . Again if B is taken midway between A and C, so that AB and BC have each the same value, say 30 feet, then

$$CD = \frac{30' \times 60'}{30' - 30'} = \infty$$

or the point D is at an infinite distance from C and the lines  $cd$  and  $c'd'$  (Fig. 4) are parallel to each other and to the line AC; a demonstration of the statement made regarding the first method of prolonging a line, namely, that in selecting the points A, B and C on the line AC, they must be so taken that B *shall* not be midway between A and C.

Finally, if AB be less than the segment BC, as, for example,  $AB = 10'$ , and  $BC = 15'$ , then

$$CD = \frac{15' \times 25'}{-5} = -75'$$

or the point D will fall 75' to the left of C, or on the *same side of the obstruction*

as the points A, B and C, as illustrated in Fig. 5. In practice the second and third results are never likely to occur. For, if the line be prolonged by the second method, neither *can* occur, since as  $ac$  is *so taken* as to pass the obstruction, the point B the conjugate of D *cannot possibly* fall so that AB shall be equal to or less than BC. When the first method is used the points A, B and C are taken at pleasure and may, therefore, be so taken as to avoid all trouble.

The accuracy of Eq. A, may be tested graphically, by assuming different values for AB and BC, laying them off to a scale on a right line, drawing from A *any* two lines as  $Ab$  and  $Ac$  of indefinite length, from B *any one* line cutting those from A in any two points as  $d$  and  $b$ ; from C two lines through  $d$  and  $b$  cutting the two from A at  $a$  and  $c$  respectively, and drawing  $ac$  till it meets AC produced in D. Then, measuring CD by the scale used to lay off AB and BC, the value obtained for CD should agree with that found by substituting the values assumed for AB and BC in Equation A.

## THE ARCHITECTURE OF LIGHTHOUSES.

From "The Builder."

LIGHTHOUSE architecture has very generally been entrusted of late to the engineer rather than to the architect. No doubt, however, can be thrown upon the statement that the problem to be solved is for the most part purely architectural. The first question raised is necessarily that of site. The reasons for erecting a lighthouse in any particular spot are indicated by Nature herself. A shore-light may have two distinct meanings. It may be a beacon, to warn from danger, or a sign of invitation to enter a place of safety. Lighthouses of the first order, however, are rather to be regarded as topographical land-marks. They are usually placed on capes or headlands, and indicate, for a distance of from ten to thirty marine leagues, the general outline and configuration of a coast. From this first order of distinct

lights the importance of the signals in question descends to that of lights of the second, third, fourth, and fifth orders,—the last being signals placed on shoals or sand-banks, or on piers at the entrance of a port for the guidance of mariners at the very moment of coming into harbor.

The selection of site is always the first care of the architect. In regarding the site of a lighthouse his skill must be aided by the experience of the sailor and of the marine surveyor. Attention must next be turned to that of the preparation of the foundation. For distant lights this is usually a simple matter. In some cases, on the contrary, the utmost skill of both the architect and the engineer is taxed in order to provide an unassailable security for the base of a tower. This is especially the case when the light is intended to serve for a beacon or warning

to ships near at hand, as well as to form a distant light to indicate the bearing of a coast. Such was the case with that dangerous rocky shoal which lies in the chops of the Channel, about fourteen miles to the south-west of Plymouth Roads. A small point of rock alone appeared above the water; the rest of the shoal, stretching some 180 yards from north to south, is always covered by the sea. This rock is the first obstacle encountered by the heavy rolling waves of the Atlantic, and lies in the most direct course for an inward bound vessel.

From this visible point, fretted by the waves, the rock descends almost perpendicularly to a depth of from 30 to 65 fathoms. The result of this opposition of a vertical submarine wall is to throw the incoming waves, when urged by any considerable wind, with a prodigious leap into the air. A height of from 150 feet to 200 feet is said to be at times attained. It was the construction on this unusually dangerous and exposed situation of the famous Eddystone Lighthouse, by Smeaton, the engineer, which seems to have secured to his profession, thus far, something of a monopoly of the construction of lighthouses.

In old times, however, the *Phari*, or light-towers, were among the most famous of the works of the architect. The name of Apollodorus, the famous architect of the Emperor Trajan, is yet associated with the port, breakwater, and Pharos of Civita Vecchia. The word *Pharos*, by which name so many lighthouses are now called, especially by the French, is of Egyptian origin. It was derived from the Island of Pharos, on which the famous lighttower of Alexandria was built. First given to the tower in question, it was thence imposed on similar structures. Such, at least, is held to be the force of the line of Statius,—

"*Lumina noctivagæ tollit Pharus æmula lunæ.*"

The classical scholar will observe that the quantity of the word *Pharos*, as determined by this line, disposes of the derivation which has been sometime proposed from the Greek verb, meaning to shine.

This famous tower was of a quadrangular form. It rose in the midst of an *enceinte* of 220 yards on each side, containing accommodation for a garri-

son. It was situated at the eastern angle of the new port of Alexandria, in a line with the point called Pharaglion. It was commenced under the reign of Ptolemy Soter (B.C. 324 to 285), and completed under his successor, Ptolemy Philadelphus B.C. 285 to 247. Its architect was Sostratus of Cnidus; and it bore an inscription dedicatory to the gods protectors of mariners. The legend is to the effect that the name of Ptolemy alone appeared over the gate of the tower when first completed. This commemoration, however, was made in plaster; on the subsequent decay of which the name of Sostratus appeared, graven in marble. The height of the tower is stated at a little more than 150 feet. The structure has been represented as a Doric base, with columns and pilasters, surmounted by seven blocks of masonry, decreasing in size, each finished with a projecting cornice. On the top of the whole an immense fire was kept burning by night, which was visible at sea twenty marine leagues off. The interior was chambered, and the position of the staircase was indicated by that of the windows. The Arab writer, Abulfeda, speaks of this Pharos as existing in his time, the thirteenth century. It has been described also by Edrisi, who lived at the commencement of the twelfth century. It ranked among the seven wonders of the world. Few vestiges can now be traced of this famous building. The modern Pharos of Alexandria is a new tower erected at another point.

While the Pharos of Alexandria is the most famous lighthouse of antiquity, it is not the most ancient. On the promontory of Sigæum, in the Troad, a lighthouse is said to have existed 650 years B.C., which served as a landmark by day, as well as for a beacon at night. And three centuries or more earlier than this, the vessels of the Greeks, returning from the siege of Troy, are said to have been lured on to the shoals near the island of Negroponte by fires lighted by the King of Eubœa with that design.

Another of the famous seven wonders of the world was the Pharos of Rhodes. This was a bronze statue, of upwards of 100 feet in height, according to Pliny, dedicated to Apollo. It stood astride on two blocks of masonry, which formed

the entrance to the port of Rhodes; and held aloft a sort of censer in its right hand, in which a beacon fire was kept alight by night. This colossus was erected by the citizens of Rhodes, in memory of the siege sustained against Demetrius, king of Macedon. It is said to have been actually constructed of masonry, covered with metal plates. It was overthrown by a violent earthquake in the year 224 A.D.

A lofty and very ancient tower looks down upon the Atlantic Ocean from the entrance of the port of Corunna, in Spain. It is called the Pillar of Hercules; and it is thought that the name Corunna is a corruption of the word "columna." By some writers the origin of this tower is attributed to the Carthaginians; by others to Caius Servius Lupus, who dedicated it to Mars. It was restored by Julius Cæsar; and again restored by Trajan. Its architectural form betrays an origin of a very remote date. There is a tradition that it was erected by an early king of Spain, in heroic times.

At Ravenna a large square tower which stands out from the side walls of the Church of Santa Maria in Porta Fuori is now used as a campanile or bell-tower. It is said to have formerly been the Pharos of the port which Augustus constructed at this point. In the fifth century the silting up of the Adriatic littoral (which is now threatening the destruction of the lagoon of Chioggia) had so obliterated the port of Augustus that its site was converted into gardens.

The Pharos of Boulogne is one of the most ancient in France. It was erected by Caligula (A.D. 38-41), on his expedition into Gaul, according to Suetonius. For many ages this tower was known by the name of the *Turris ardens*. Its base was octagonal, each side measuring eight mètres, according to the design given by Montfaucon. It consisted of twelve stories, each smaller than the one below it, and each surmounted with a cornice. In the year 807, Charlemagne ascended this tower in order to review his army, and ordered that the long-extinguished beacon should be re-kindled. Various colored stones, brown, red, and yellow, were employed in constructing the different parts of this Pharos, with the aim of rendering it a more strikingly

visible object. In 1545 the English made use of the tower as a fortress. Their works seem to have interfered with the solidity of the foundation, for in 1644 the tower fell.

Under Claudius, whose tenure of empire lasted from A.D. 41 to A.D. 54, a tower was erected, according to Suetonius and Dion Cassius, at Ostia, in imitation of the Pharos of Alexandria. In the fifteenth century it was visited and described by Piccolomini, who was afterwards pope, under the name of Pius II., from 1458 to 1464. From a bas-relief in the possession of Prince Torlonia, it is deduced that this tower was built, as that at Boulogne was previously described to have been, in successively diminishing planes or stories, with a fire kindled on the top. The elevation, however, which is produced by Signor Cialdi, in his learned memoir on lighthouses, from which very much of our information is derived, is that of three towers, of diminishing sizes, standing one on another, with a thick short column on the top supporting the beacon or bonfire. The deposits brought down by the Tiber have long filled up the Claudian port of Ostia; and the careful measurements which have been made by the Italian engineers of the position of the shore line at successive historic epochs, indicate that a geological undulation, similar to that witnessed by the famous temple of Serapis, at Pozzuoli, on the Bay of Naples, has occurred at the mouth of the Tiber.

The restoration of the lighthouse built by the Emperor Trajan at Civita Vecchia has been effected by the present Pope, Pius IX. The architect, Apollodorus, by Trajan's command, designed and carried out a commodious port at Civita Vecchia. A breakwater, or island, was placed before the entrance of the harbor, to protect it from the waves. Two towers were erected on this work, one of which sustained a beacon. In the *Itinerarium*, a journey through Etruria, of Numazianus, who lived in the fourth and fifth centuries of our era, the double towers and double entrance of the port are commemorated in hexameter verse. Neglect, and the action of the sea, gradually filled the port; and in the pope-dom of Gregory IV. (A.D. 828-844) it is spoken of as having been intentionally

ruined, for fear of being seized by the Saracens, and used by them as a naval centre. Under Urban VIII. it was repaired and re-opened. In 1616, Paul V., among other improvements, rebuilt the existing eastward tower. The westward towers were still in ruins at the commencement of the present century. It was commonly called *Il Marzocco*. Pope Gregory XVI. reared a small fort on its ruins, but no better signal was offered to navigators than a light hoisted on a mast. In 1860, Pius IX., consulted the illustrious astronomer, Padre A. Secchi, as to the lighthouse, and the present tower was built, and furnished with a Fresnel illuminating apparatus of the second order. The tower is of stone, cylindrical in form, and carries a lantern 110 feet above the level of the sea. The works were executed by the engineer Chevalier Giovanni Minti.

The Cordovan Pharos is a tower of admirable construction, reared on a rock at the mouth of the Gironde. The name is taken from that of an architect, who, about A.D. 830, built a tower in the island of Andros. Both town and island were engulfed by the sea in the earthquake of 1427. The present town stands on a shoal, seaward of the former Pharos, which is covered with three mètres of water at high tides. It was commenced in 1545 by the Parisian architect, Louis D. Foix, by command of King Henry II. It was continued by Henry IV. in 1601, and finished under Louis XIV. in 1665. In 1778 the upper part of the tower was removed, and replaced by a frustrum of a cone, rising to 78 mètres from the foundations, by the architect Theulere. The tower is composed of a series of galleries rising one above another, ornamented with pilasters and friezes, and gradually diminishing in dimensions. From the second story a fine staircase conducts to the top of the cone. The latter is divided into four stages, on the last of which the lantern is placed. A wall surrounds the base, the diameter on the plan being 43 mètres. Within this are situated the rooms of the guardians, almost in the form of casemates. It is claimed for this Pharos that it is the finest edifice of the kind in the world. In 1790 a reverberating light was placed on this tower. In 1854 a dioptric Fresnel apparatus was substi-

tuted, with a light of the first order, eclipsing from minute to minute.

The beautiful Torre del Capo at Genoa is well known to all familiar with that picturesque Italian port. Originally built on the promontory of San Berrigue in 1139; it was first illuminated in 1326. It was removed in 1512, and rebuilt, by the Republic, in 1643. It is a square tower, in two stories, with battlemented terraces, the lower portion nine mètres square, the upper seven. Rising from a rock 42½ mètres above the sea, it carries its light at the height of 118.5 meters above the water. In 1841 it was fitted with a Fresnel lenticular apparatus of the first order. For beauty and elegance of structure, this historic Pharos is one of the first in existence.

The Pharos of Meloria was built by the Pisans in 1154. It indicated the direction to be taken by ships making for Portopisano, and gave warning of a dangerous sand-bank. This tower was destroyed by Charles of Anjou in 1267, by the Genoese in 1287, and by the Guelfs in 1290. Having determined to abandon Meloria, the Pisans erected, in 1304, the lighthouse which still exists near Leghorn. It is celebrated by Petrarch. It stands near the entrance of the harbor, to the south of the new curvilinear mole; and rises 47 meters above the level of the sea. It is built of stone, in the form of two battlemented cylinders, surrounded at the base by a polygonal inclosure of thirteen sides.

On the shore extending from the extreme promontory of Istria as far as Chioggia, no lighthouse was in existence in 1818. In that year the flame was kindled on the Pharos of Salvore, which was built by the architect Nobili, on the Punta delle Mosche, twenty Italian miles from Trieste, and five from Pisano. Here occurred the first instance of the use of gas for lighthouse purposes. The tower is cylindrical, of wrought stone work, with a cornice above, and a quadrangular base. Its diameter is five meters, and the diameter of the cornice is 6.3 meters. An internal staircase leads up to the octagonal lantern, 4.4 meters high, and 3.8 meters in diameter, at the height of 35.5 meters above the level of the sea. The apartments for the attendants are in the square base of the tower.

The example followed more or less directly by the architect Nobili, as well as by George Stephenson in his plans for the Bell Rock lighthouse, built by him in 1808, at Inchcape, near Arbroath, was no doubt the great work of Smeaton before referred to, the Eddystone Lighthouse. The wonderful triumph attained at this most difficult and dangerous spot was without precedent among any of those ancient and famous Phari to which we have referred. The first attempt to raise a lighthouse to give warning of this destructive shoal was made by Winstanley in 1696. A base of stone, 15 feet in diameter, and 12 feet high, was built on the rock and fastened to it with iron cramps. On that was built the tower, 70 feet high to the vane. On the night of the 14th November, 1698, the light was first kindled. As the waves broke over the lantern at this height, an addition of 20 feet of masonry, and of 40 feet of metal work, was subsequently made, the wall of the tower being made a yard thicker at the same time. In November, 1703, it became evident that repair was necessary. Winstanley betook himself to the tower, expressing his confidence in its ability to withstand the utmost fury of the elements. On the night of the 26th of that month a fearful storm occurred, and the lighthouse had entirely disappeared by the morning. It is said that on the same night the model of the tower, which the builder had kept in his house in Littlebury, in Essex, fell down and broke into fragments.

In consideration of the great importance of the case to navigation, Parliament, in 1706, authorised the imposition of a light due on the vessels frequenting this part of the Channel, and a contract for a new lighthouse was made. A silk merchant, of the name of Rudyerd, undertook the erection. His plan was that of a plain wooden cone, lined with masonry, the idea being at the same time to provide weight for stability, and to oppose a smooth surface to the impinging waves. This tower was 20 feet in diameter at the base, 14 feet at the top, and 62 feet high. The lantern was octagonal, 10 feet in external diameter, and 9 feet high. A globe of 32 inches diameter stood on the top of the lantern, at the height of about 90 feet above the

level of the sea. After long and costly work this tower was completed in 1709. On the 2d of December, 1755, it disappeared in a few hours in a terrible conflagration, the origin of which is unknown. This unexpected destruction, owing to the fury of that element against which the builder had taken no thought to provide, furnishes a most instructive lesson as to the material necessary to employ for similar structures.

In 1756 Smeaton for the first time visited the Eddystone rock. The idea of the form to be given to the building he took from the trunk of an oak, as that provision which Nature herself had made for the most successful resistance to the play of the wind. A model made on this idea was approved by the Trinity House and by the Government, and Smeaton commenced the work in the August of 1757. The stone which he selected was the granite of Hingstone Downs, fifteen miles from Plymouth, for the exterior, Portland stone for the interior, and a mixture of Aberthaw lime and Roman pozzolana for cement. The stones at the base of the tower were bird's-mouthed and dove-tailed into each other and into the rock, so as to form an absolutely homogeneous structure. From August 27th to September 14th, 167 hours were employed in filling in the foundations. The utmost care was taken in the fitting and bonding of the stone, each stone being exactly worked, and fitted to those by which it was to be set, on shore, before sending to the tower. By August 8th, 1758, the work had been raised to the height of thirty-two feet, and the first store-room contrived in the tower was complete. On March 21st, 1759, Smeaton visited the spot, and found everything perfectly uninjured. From July 5th to August 7th, in that year, another thirty-four feet had been added to the height. The metal work of the lantern had been prepared under Smeaton's inspection in London, and the ball which formed the summit of the structure was fixed by his own hands at ninety-two feet above the level of the sea. The solid base rose for sixteen feet, at which height a door gave access to the internal spiral staircase.

On the night of the 16th of October, three years, ten months, and sixteen days after the conflagration of the work of

Rudyard, the light was kindled in the lantern of Smeaton's Eddystone lighthouse. It has ever since given uninterrupted warning of the dangerous vicinity. Many violent storms have burst over it, especially that of January, 1762; but it has remained uninjured, although a distinct oscillation is felt in the lantern in violent winds. The calculation of the height of the waves that dash over this noble work makes them rise to the height of 162 feet above the level of the sea, giving a column of water containing from two thousand to three thousand metric tons. The necessity for the utmost exactitude in the joints of the masonry is thus apparent. When water exerts a battering force of this nature, its effect, if it gets under or within a building, is irresistible, while it breaks into foam against a smoothed and curved surface.

On the 24th October, 1877, Sir William Thomson, professor of natural history in the University of Glasgow, gave a lec-

ture before the Shipmasters' Society on the subject of lighthouses; the point to which he chiefly directed attention, however, being not their architectural structure, but the character of their illumination. Ninety per cent. of our local lights are fixed; and the danger that they may be mistaken is said by the lecturer to be far greater than in the case of revolving or eclipsing lights. An eclipse, however, of from fifty to sixty seconds is far too long in dirty weather, and the eye may readily lose the point of light before its bearing has been correctly taken. The Craigmoor light, in the Firth of Clyde, has been fitted with a light of Sir William Thomson's own arrangement,—a long and a short eclipse alternate hours, and there is thus a short pause, giving sixteen seconds of unbroken light. This combination of flashes is made to signify the letter C, according to the Morse alphabet, a very beautiful application of one of the latest improvements in telegraphy.

## A NEW GENERAL METHOD IN GRAPHICAL STATICS.

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### I.

ALL general processes used in the graphical computation of statical problems consist, in their last analysis, in a systematized application of the proposition known as the "parallelogram of forces," which states that if two forces be applied to a material point, and if they be represented in magnitude and direction by two determinate straight lines, then their resultant is represented in magnitude and direction by the diagonal of a parallelogram, two of whose sides are the just mentioned determinate lines. This is the basis of all grapho-statical construction, but the methods by which it is systematized, and the auxiliary ideas incorporated in the processes, have so enlarged its possibilities of usefulness, that Graphical Statics may perhaps claim to be a science of itself;—the science of the geometrical treatment of force.

In order to introduce to the public a new set of auxiliary ideas, which shall constitute a new method, of a character equally general with that now in use and known as the "equilibrium polygon method," it has seemed best to give, in the first place, a brief review of the principal ideas already employed by the cultivators of this science.

#### RECIPROCAL FIGURES.

When a framed structure, such as a roof or bridge truss, is subjected to the action of certain weights or forces, these applied forces form a system which is in equilibrium. Now any system of forces in equilibrium may be represented in magnitude and direction by the sides of a closed polygon, a fact which follows at once from the doctrine of the parallelogram of forces. Such a polygon is called the polygon of the applied forces.

Again, the forces which act at any joint of a frame are in equilibrium, and hence there is a closed polygon of the forces acting at each joint. The forces which meet at a joint of a frame are the longitudinal tensions or compressions of the pieces meeting at that joint together with any of the applied forces whose point of application may be the joint in question. Draw a diagram of the frame and the applied forces all of which we will suppose lie in a single plane. Call this the "frame diagram": it represents the position and direction of all the forces acting in and upon the frame. The frame diagram necessarily has at least three lines meeting at each joint. A piece which constitutes part of the frame does not necessarily have both its extremities attached at joints of the frame; one extremity may be firmly attached to any immovable object. The frame diagram is, therefore, not necessarily made up of closed figures.

Now draw the closed polygon of the forces applied to the frame, and at each of the joints where forces are applied draw the closed polygon of the forces which meet at that joint, using so far as possible the lines already drawn as sides of the new polygons, and at the same time draw polygons for the forces acting at each of the remaining joints. If this process be effected with care as to the order of procedure, as well as to the order in which the forces follow each other in the polygon of the applied forces, then the resulting "diagram of forces," which is formed of the combination of the polygon of the applied forces with the polygons for each joint, will contain in it a single line and no more parallel to each line of the frame diagram. In that case the force diagram is said to be a reciprocal figure to the frame diagram. If sufficient care is not exercised in the particulars mentioned, some of the lines in the force diagram will have to be repeated, and the figure drawn will not be the reciprocal of the frame diagram, nevertheless it will give a correct construction of the quantities sought.

If the frame diagram and the force diagram are both closed figures then they are mutually reciprocal. The properties of reciprocal figures were clearly set forth by Professor James

Clerk Maxwell, in the *Philosophical Magazine*, vol. 27, 1864; in which is stated, what is also evident from considerations already adduced above, that mutually "reciprocal figures are mechanically reciprocal; that is, either may be taken as representing a system of points (*i.e.* joints) and the other as representing the magnitudes of the forces acting between them."

The subject has also been treated by Professor B. Cremona in a memoir entitled "*Le figure reciproche nelle statica grafica.*" Milan, 1872.

We shall now give examples of this method of computing the forces acting between the joints of a frame, together with certain extensions by which we are enabled to treat moving loads, etc. The method is correctly called "Clerk Maxwell's Method." The notation employed, which is particularly suitable for the treatment of reciprocal diagrams, is due to R. H. Bow, C.E.; and is used by him in his work entitled "*Economics of Construction.*" London, 1873. In this work will be found a very large number of frame and force diagrams drawn by this method.

Let the right hand part of Fig. 1 represent a roof truss having an inclination of  $30^\circ$  to the horizon, of which the lower chord is a polygon inscribed in an arc of  $60^\circ$  of a circle. If the lower extremities of the truss abut against immovable walls a change of temperature causes an horizontal force between these lower joints, the effect of which upon the different pieces of the truss is to be constructed. No other weights or forces are now considered except those due to this horizontal force. This force is considered thus apart from all others because it is a force between two joints, and must enable us to obtain a pair of mutually reciprocal figures, such as weights and other applied forces seldom give.

It is seen that the force between these joints might be supposed to be caused by a tie joining these points; and in general it may be stated that the diagram of forces due to any cambering or stress induced in a frame by "keying" pieces, is mutually reciprocal to the frame diagram.

Let any piece of the frame be denoted by the letters in the spaces on each side

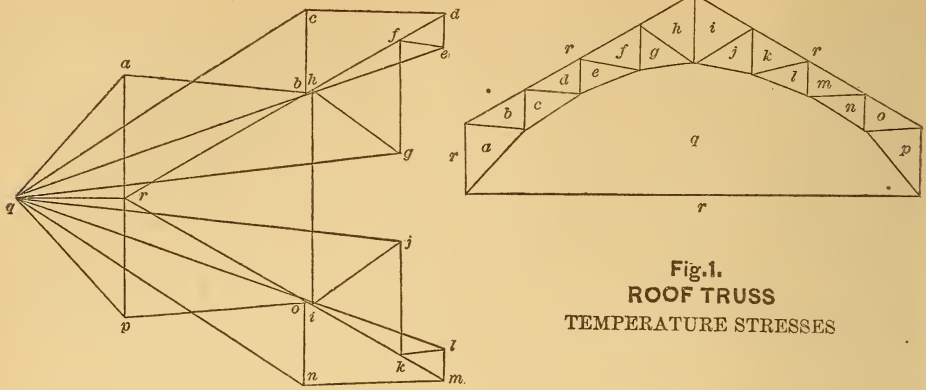


Fig. 1.  
ROOF TRUSS  
TEMPERATURE STRESSES

of it; thus the pieces of the lower chord are  $qa$ ,  $qc$ ,  $qe$ , etc.; and those of the upper chord are  $rb$ ,  $rd$ , etc., while  $ab$ ,  $bc$ , etc., are pieces of the bracing, and  $qr$  is the tie whose tension produces the stress under consideration.

In the force diagram upon the left, let  $qr$  represent, on some assumed scale of tons to the inch, the tension in the piece  $qr$ ; and complete the triangle  $agr$  with its sides parallel to the pieces which converge to the joint  $agr$ ; then must this triangle represent the forces which are in equilibrium at that joint. Next, with  $ar$  as one side, complete the triangle  $abr$ , by making its sides parallel to the pieces meeting at the joint of the same name:—its sides will represent the forces in equilibrium at that joint. In a similar manner we proceed from joint to joint, using the stresses already obtained in determining those at the successive joints.

It is not possible to determine in general more than two unknown stresses in passing to a new joint, unless aided by some considerations of symmetry which may exist at such a joint as  $ghijq$ .

Now from the left hand figure as a frame diagram, in which stresses are induced by causing tension in the tie  $qr$ , we can construct the right hand figure as a force diagram, but it must be noticed in that case that  $rb$ ,  $rh$ ,  $rf$ ,  $rd$  are separate and distinct pieces meeting at the joint  $r$ , although they all lie in the same right line, and that the same is true along the line  $oikm$ .

One or two considerations of a general nature should be recalled in this connection.

A polygon encloses the space  $q$ ; in

the reciprocal figure the lines parallel to its sides must all diverge from the point  $q$ : and if the upper chord had been a polygon, instead of being of uniform slope, the lines parallel to its sides would diverge from the point  $r$ . As it is,  $ra$ ,  $rb$ ,  $rd$ ,  $rm$  etc., form the rays of such a pencil, in which several rays are superposed one upon another.

The determination of the question as to whether the stress in a given piece is tension or compression is effected by following the polygon for any joint completely around and noting whether the forces act toward or from the joint: *e.g.* at the point  $fghrf$ , from following the diagrams of preceding joints in the manner stated, it will be found that  $fg$  is under tension, and acts from the joint; consequently,  $gh$  which acts toward the joint is under compression, as are also the two remaining pieces. Hence if the tension in the tie  $qr$  be replaced by an equal compression in a part, tending to move the lower extremities of the roof from each other, the sign of every stress in the roof will be changed, but the numerical amount will remain unchanged, and no change will be made in the force diagram.

#### ROOF TRUSS.

As another example let us take a roof truss represented in Fig. 2, acted upon by the equal weights  $fe$ ,  $ed$ ,  $dd'$ , etc. Suppose that the effect of the wind against the right hand side of the truss is such as to cause a deviation of the force applied at the joint  $a'b'e'f'$  of the amount indicated in the figure. Such a deviation may of course occur at several joints of a roof, but the treatment of

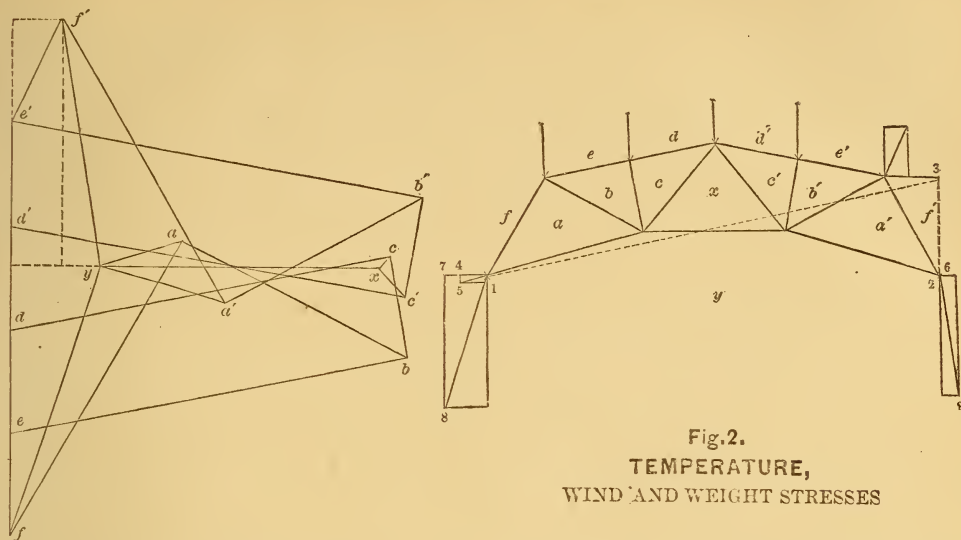


Fig.2.

TEMPERATURE,  
WIND AND WEIGHT STRESSES

the single joint at which the force of the wind is, in this case, principally concentrated, will sufficiently indicate the method to be employed in more intricate examples.

Suppose that this pressure of the wind is sustained by the left abutment. The manner in which it is really sustained depends upon the method by which the roof is fixed to the walls.

This horizontal pressure of the wind is not directly opposed to the thrust of the left abutment, consequently a couple is brought into play by these forces, whose effect is to transfer a part of the weight from the right to the left abutment. To compute the amount of this effect, draw an horizontal line through this joint (or in case the wind acts at several joints the horizontal line has to be drawn through the center of action of the wind pressure) and prolong it until it intersects the vertical at the right abutment at 3. Let 14 be equal to the pressure of the wind. Join 13 and prolong 13 until it intersects the vertical through 4 at 5, then is 45 the amount by which the weight upon the left abutment is increased, and that upon the left abutment decreased. For, let  $k. 14 = 12$ . then  $k. 45 = 23$ . Now the couple due to the wind  $= 23 \cdot 14$  but  $k. 23 \cdot 14 = 12 \cdot 23 = k. 12 \cdot 45$ ,  $\therefore 23 \cdot 14 = 12 \cdot 45$ . The right hand side of this last equation is the couple equivalent to the wind couple, having the arm 12 and

a pair of equal and opposite forces represented by 45. Let 45 be added to half the weight of the symmetrical loading upon the roof to obtain the vertical reaction of the left abutment, and subtracted from the same quantity for the vertical reaction of the right abutment.

If any doubt occurs as to the manner in which the wind pressure is distributed between the abutments that distribution should be adopted which will cause the greatest stresses upon the pieces, or, as it may be stated in better terms, each piece should be proportioned to bear the greatest stress which any distribution of that pressure can cause.

Let us suppose that a horizontal compression is exerted upon the truss due to temperature or other cause, and represented by the width 26 of the rectangle at the right abutment, then the reaction at that point is the resultant 92 of this compression and the vertical reaction; while at the left abutment the total horizontal reaction 71 is the sum of this compression and the resistance called into action by the wind, giving 81 as the resultant reaction at the left abutment.

Now, using a scale of force twice that just employed, for the sake of greater convenience and accuracy, construct  $defyf'e'd'$  the polygon of the applied forces; and proceed to construct as in Fig. 1 the polygons of forces for each of the joints. The accuracy of the construction will be tested by the closing

of the figure at the completion of the process.

The force diagram at the left is the reciprocal figure of the diagram of the frame and applied forces at the right, but the figure at the right is not the reciprocal of that at the left since it is not a closed figure with at least three lines meeting at each intersection.

#### BRIDGE TRUSS.

As a further example take the bridge truss shown in Fig. 3, which is represented as of disproportionate depth in order to fit the diagram to the size of the page. The method employed is a simplification of that given by Mr. Charles H. Tutton on page 385, vol. XVII of this Magazine.

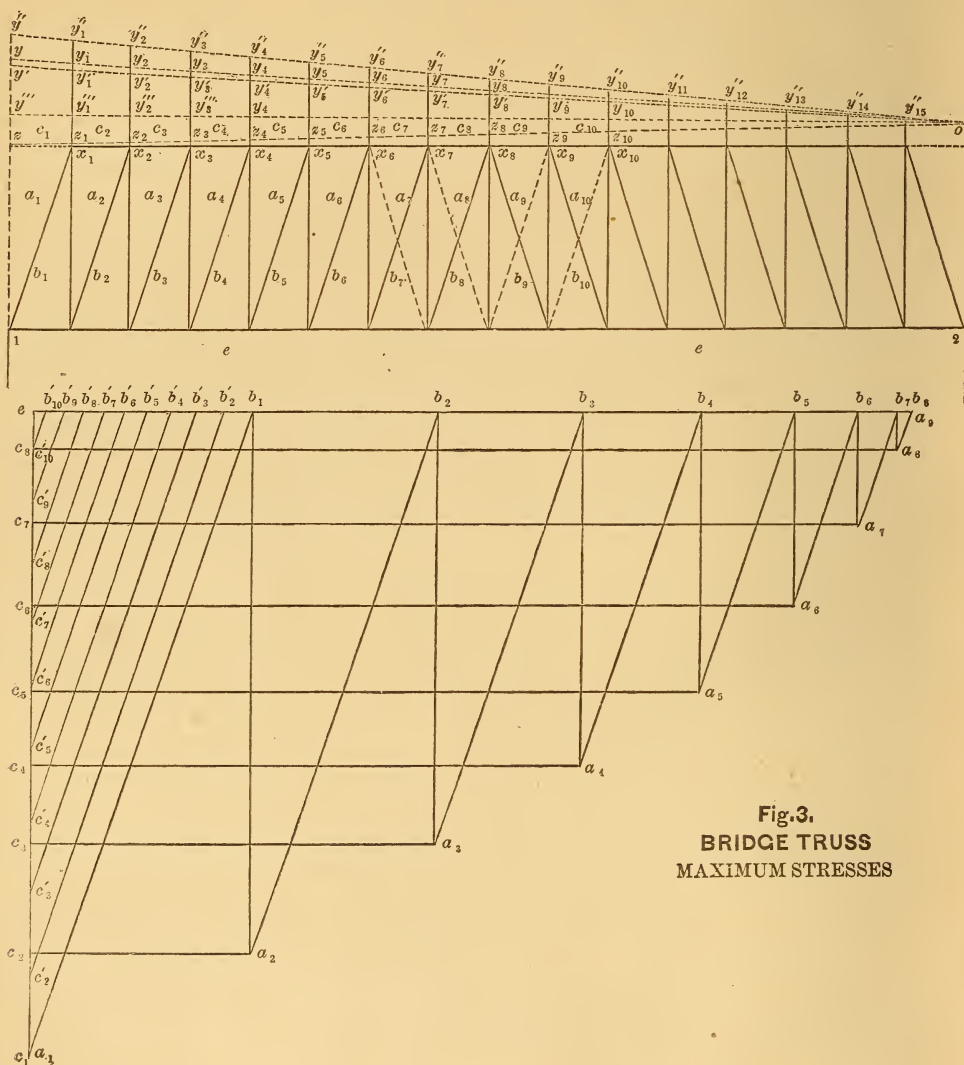


Fig. 3.  
BRIDGE TRUSS  
MAXIMUM STRESSES

Let us suppose the dead load of the bridge itself to consist of a series of equal weights  $w$ , applied at the upper joints  $x_1, x_2$ , etc., of the bridge. Let each of these weights when laid off to scale be represented by the length of

$zy''' = w$ , then the horizontal lines  $xx$  and  $y'''o$  include between them ordinates which represent these weights.

Let the live load consist of one or more locomotives which stand at the joints  $x_1$  and  $x_2$ , and a uniform train of

cars which covers the remaining joints. Let the load at each joint due to the cars be represented by  $y''y' = w'$ , and the excess above this of the load at each of the joints covered by the locomotives be represented by  $y'y'' = w''$ ,  $\therefore w + w' + w'' = c_1c_2 = zy'' = c_2c_3$  is the load at  $x_1$  and at  $x_2$ , and  $w + w' = c_3c_4 = zy'$  is the load at  $x_3$  and at each of the remaining joints.

Draw  $y'o$ ,  $y''o$  and  $zo$ , then is  $z_1y_1'' = \frac{1}{6}zy''$  that part of the load at  $x_1$  which is sustained at the left abutment, as appears from the principle of the lever. Again  $z_2y_2'' = \frac{1}{6}zy''$  is that part of the load at  $x_2$  sustained by the same abutment, and  $z_3y_3' = \frac{1}{6}zy'$  is a similar part of load at  $x_3$ . Let the sum of these weights sustained by the left abutment be obtained; it is  $c_1e$  upon the lower figure. Upon  $c_1e$  lay off  $c_1c_2 = w + w' + w''$ ,  $c_2c_3 = w + w' + w''$ ,  $c_3c_4 = w + w'$ , etc., equal to the loads applied at  $x_1$ ,  $x_2$ , etc. We are now prepared to construct a diagram of forces which shall give the stresses in the various pieces under this assumed loading. Before constructing such a diagram, we wish to show that the assumed position of the load causes greater stresses in the chords of the bridge than any other possible position. The demonstration is quoted nearly verbatim from Rankine's Applied Mechanics, and though not strictly applicable to the case in hand, since it refers to a uniformly distributed load, it is substantially true for the loading supposed, when the excess of weight in the locomotives is not greater than occurs in practice.

"For a given intensity of load per unit of length, a uniform load over the whole span produces a greater moment of flexure at each cross section than any partial load."

"Call the extremities of the span 1 and 2, and any intermediate cross section 3. Then for a uniform load, the moment of flexure at 3 is an upward moment, being equal to the upward moment of the supporting force at either 1 or 2 relatively to 3, minus the downward moment of the uniform load between that end and 3. A partial load is produced by removing the uniform load from part of the span, situated either between 1 and 3, between 2 and 3, or at both sides of 3. First, let the load be removed from any part of the span between 1 and 3. Then

the downward moment, relatively to 3, of the load between 2 and 3 is unaltered, and the upward moment, relatively to 3, of the supporting force at 2 is diminished in consequence of the diminution of the force; therefore the moment of flexure is diminished. A similar demonstration applies to the case in which the load is removed from a part of the span between 2 and 3; and the combined effect of those two operations takes place when the load is removed from portions of the span lying at both sides of 3; so that the removal of the load from any portion of the beam diminishes the moment of flexure at each point."

The stress upon a chord multiplied by the height of the truss is equal to the moment of flexure; hence in a truss of uniform height the stresses upon the chords are proportional to the moments of flexure, and when one has its greatest value the other has also.

The sides of the triangle  $c_1eb_1$  represents the forces in equilibrium at the joint  $c_1eb_1$  at the left abutment 1. The polygon  $c_2c_1b_1a_2c_2$  represents the forces in equilibrium at the joint of the same name, i.e., at the joint  $x_1$ . The forces at the other joints are found in a similar manner.

It is unnecessary to complete the figure above  $e$  unless to check the process. The stresses obtained for the corresponding pieces in the right half of the truss would, upon completing the diagram, be found to be slightly less than those already determined because there are no locomotives at the right. The greatest stresses upon the pieces of the lower chord are  $eb_1$ ,  $eb_2$ , etc., and on the upper chord are  $a_2c_3$ ,  $a_1c_2$ , etc.

To determine the greatest stress upon the pieces of the bracing (posts and ties) it is necessary to find what distribution of loading causes the greatest shearing force at each joint, since the shearing forces are held in equilibrium by the bracing. We again quote nearly word for word from Rankine's Applied Mechanics.

"For a given intensity of load per unit of length, the greatest shearing force at any given cross-section in a span takes place when the longer of the two parts into which that section divides the span is loaded, and the shorter unloaded."

"Call the extremities of the span, as before, 1 and 2, and the given cross-section 3; and let 13 be the longer part, and 23 the shorter part of the span. In the first place, let 13 be loaded and 23 unloaded. Then the shearing force at 3 is equal to the supporting force at 2, and consists of a tendency of 23 to slide upwards relatively to 13. The load may be altered either by putting weight between 2 and 3, or by removing weight between 1 and 3. If any weight be put between 2 and 3, a force equal to *part* of that weight is added to the supporting force at 2, and, therefore, to the shearing force at 3; but at the same time a force equal to the *whole* of that weight is taken away from that shearing force; therefore the shearing force at 3 is diminished by this alteration of the load. If weight be removed from the load between 1 and 2, the shearing force at 3 is diminished also, because of the diminution of the supporting force at 2. Therefore any alteration from that distribution of load in which the longer segment 13 is loaded, and the shorter segment 23 is unloaded, diminishes the shearing force at 3."

The shearing force at any point is the resultant vertical force at that point, and can be computed by subtracting from the weight which rests upon either abutment the sum of all the weights between that point and the abutment, *i.e.*, by taking the algebraic sum of all the external forces acting upon the truss from either extremity to the point in question; the reaction of the abutment is, of course, one of these external forces.

The greatest stress upon the brace  $a_1b_1$  is that already found, while  $x_1$  is loaded with the live load.

If the live load be moved to the right so that no live load rests upon  $x_1$ , and the locomotives rest upon  $x_2$  and  $x_3$ , the pieces  $b_1a_2$  and  $a_2b_2$  will sustain their greatest stress. To find the shear at  $x_2$  in that case, we notice that the change in position of the live load has changed the reaction  $ce$  of the left abutment by the following amounts: the reaction has been diminished by the quantity  $y_1'''y_1'' = \frac{1}{16}(w' + w'')$ , since the load at  $x_1$  has been removed, and it has been increased by  $y_3'y_3'' = \frac{1}{16}w''$ , since  $x_3$  is loaded more heavily than before, therefore the reaction of the abutment has on the whole

been decreased by the total amount  $\frac{1}{16}(15w' + 2w'')$ .

Now the shear at  $x_2$  is this reaction diminished by the load  $w$  at  $x_2$ . In order to construct it, draw  $yy_1''$  parallel to  $y'o$ , then  $yy' = \frac{2}{16}w''$ . Shear at  $x_2 = ec_1 - w - \frac{1}{16}(15w' + 2w'') = ec_1 - x_2y_1$ . Lay off  $c_1c_2' = x_2y_1$ , then the shear at  $x_2 = ec_2' =$  the greatest stress in the brace  $b_1a_2$ ; and  $b_2c_2' =$  the greatest stress in  $a_2b_2$ .

Again, to find the greatest shear at  $x_3$  when the live load has moved one panel further to the right, we have the equation: Shear at  $x_3 = ec_2' - w - \frac{1}{16}(w' + w'') + \frac{2}{16}w'' = ec_2' - w - \frac{1}{16}(14w' + 2w'') = ec_2' - x_2y_2$ . Lay off  $c_2'c_3' = x_2y_2$ , then the shear at  $x_3 = ec_3'$ , which is the greatest stress in the piece  $b_2a_3$ , while  $b_3c_3'$  is the greatest stress in  $a_3b_3$ .

In similar manner lay off,  $c_3'c_4' = x_3y_3$ ,  $c_4'c_5' = x_4y_4$ , etc., until the whole of the original reaction  $ec_1$  of the abutment is exhausted, then are  $ec_1$ ,  $ec_2'$ ,  $ec_3'$ ,  $ec_4'$ , etc., the successive shearing stresses at the end of the load, *i.e.* the greatest shearing stresses, and consequently these stresses are the greatest stresses on the successive vertical members of the bracing, while  $c_1b_1$ ,  $c_2'b_2'$ ,  $c_3'b_3'$ , etc., are the greatest stresses on the successive inclined members of the bracing.

Had the greater load, such as the locomotives, extended over a larger number of panels, the line  $y_1y_2y_3$  would have cut off a larger fraction of  $y'y''$ . Suppose, for instance, that the locomotives had covered the joints  $x_1x_3$  inclusive, then the line  $y_1y_2$  would have passed through  $y_3''$ , and been parallel to its present position. In that case the ordinates  $x_1y_1$ ,  $x_2y_2$  would have been successively subtracted from the reaction of the abutment due to a live load covering every joint, in order to obtain the shearing forces, just as at present, until we arrive at  $x_3$ , after which it would be necessary to subtract the ordinates  $x_3y_3''$ ,  $x_4y_4''$ , etc. The counter braces are drawn with broken lines. Two counters are necessary on each side of the middle under the kind of loading which we have supposed. It is convenient, and avoids confusion in lettering the diagram to let  $a_6b_6$ , for instance, denote the principal or counter indifferently, as both are not subject to stress at the same time.

The devices here used can be applied

to a variety of cases in which the loading is not distributed in so simple a manner as in this case.

#### IN GENERAL.

This method permits the determination of the stresses in any frame when we know the relative position of its pieces and the applied forces, provided the disposition of the pieces is such as to admit of a determination of the stresses.

The determination of what the applied forces are in case of a continuous girder or arch is a matter of some complexity, depending upon the elasticity of the materials employed, and the method in its present form affords little assistance in finding them.

Some authors have applied the method to find the stresses induced in the various pieces of a frame by a single force first applied at one joint, and then at another, and so on, and, finally, to find the stresses induced by the action of several simultaneous forces, by taking the algebraic sum of their separate effects. This is theoretically correct but laborious in practice in ordinary cases. Usually, some supposition respecting the applied forces can be made from which the results of all the other suppositions which must be made, can be derived with small labor. The bridge truss treated was a remarkable case in point.

## IMPROVEMENT OF THE SOUTH PASS OF THE MISSISSIPPI.\*

By E. L. CORTHELL, Resident Engineer.

IN regard to the depth of channel that exists at present through the jetties, it will be sufficient to state that on the first day of November, this year, the steamship City of Bristol, of the New York and Liverpool Inman Line, passed through the jetties without detention and without touching. Her draught was 21 feet and 8 inches, the tide at the time was  $2\frac{1}{2}$  inches below "average flood tide," which is the plane of reference established by the United States engineers.

It may not be generally understood, that the delay in obtaining the deeper channels demanded by the contract between Capt. Eads and the United States Government has been caused mainly by the difficulties which have been met with in deepening the river shoal at the head of the Passes.

First, there was not a full knowledge and comprehension of all the conditions existing, nor of their relation to each other, and to the channel, which it was necessary to make into South Pass; secondly, it was necessary that the works should be partly tentative in their nature, and this fact demanded considerable time in which to observe their effects; thirdly, many months were consumed in building these extensive works which

would control the whole volume of the river. All these causes have delayed the formation of the channel through the bar at the Gulf, where the jetties are located. Without entering beyond a few explanations into the discussion of this most difficult and interesting problem of river hydraulics, on which a treatise could well be written, we simply refer to the fact of its existence and of its intimate relation to the channel through the jetties.

There are conditions existing of so subtle a nature, with relations so obscure and yet so entirely dependent upon each other; there are hidden causes, that operate so quietly and easily, to change existing conditions and to destroy the equilibrium of natural forces; there are at times such unlooked-for results from the works constructed, and there are so many occult principles and unknown laws in the flow of water moving in immense volumes that are elucidated by these results, that in the end, one of the most useful and interesting histories may be written, that will record in detail all the steps which have been taken to persuade the waters of the great river to go where man directs.

With all the interest that may attach to the subject in the mind of a disinterested person, who views it all calmly

\* A letter to the *Providence Journal*.

from a distance, yet by those who have not only their reputations but their financial prospects at stake in the success of these jetties, it is deeply regretted that the completion of the work and the securing of the maximum channel has been delayed so seriously, and the success of the enterprise endangered by what appears now to have been false economy, which decided upon the improvement of the South Pass rather than of the South-west Pass.

To improve, by the force of river currents, a shoal which lies as a great middle ground between the two main outlets of the river, is one of the most difficult of undertakings. To induce the river to leave the channels in which it has flowed for ages, and to seek a new and untried one, is in opposition to its conservative nature; it hesitates long, and is very loth to leave the old ways for the new.

It is necessary to show this almost sentient monster that there are sound hydraulic reasons for changing its ancient habits.

All the works that are built in the funnel-shaped mouth of South Pass, have a tendency to throw a part of its volume into the two large passes, which stand right there with their great, hungry mouths to take every drop that comes within their reach.

To avoid this result of our works, it has become necessary to hold the sections of these passes *in statu quo* by laying on their beds a sill of willow mattresses, from our works, at the head of South Pass, to the east and west banks of the river.

The total length of these sills is about one mile and a quarter. They are simply the foundations of more extensive works of the same kind, by which we expect to control, slowly but surely, the whole river volume, and draw from it, what South Pass needs to obtain and maintain, a channel, thirty feet deep and 350 feet wide, to the deep waters of the Gulf of Mexico.

Another subject which we wish to refer to, especially, is the "re-formation" of the bar in front of the jetties; that "re-formation" that has been held up by some of our friends, as the great, final and grand obstacle to our success.

In the earlier stages of the work, it

was the impossibility of securing even a twenty foot channel that troubled them; the absurdity of our expecting any such result was so clearly patent to their minds that they thought their argument unanswerable, and convinced themselves any rate of our prospective failure; but the 20 foot channel came, then the 21, now nearly the 22, and through the jetties a broad, deep channel from 24 feet to 95 feet deep, has made its appearance, and has thus steadily and surely furnished us facts for our arguments that 30 feet would surely come.

Of late we hear but little of the absurdity of our intention to obtain a deep channel; but now it is *that bar*, that *new bar* that is to form so rapidly, close up the jetty outlet and bring disaster upon the whole enterprise!

Well, it is now two years and a half since we laid the first willow mattress on the South Pass bar. The same enormous volume of mud and water has flowed out through the jetties that formerly spread out like an open fan a mile and a half in width, and in addition to it nearly four million cubic yards of sand and clay have been excavated from the shoal at the head of the Pass and from the channel between the jetties and thrown out into the gulf.

The arguments on either side have facts now, or the absence of them, to prove or disprove the conflicting theories. The time has come when the American people who are to pay for this great work can demand the facts, that they may know whether all the money expended and to be expended, is irretrievably lost in a mud bank that will pay no dividend to its depositors, or will result in a deep and permanent outlet for the Mississippi Valley.

In the limited space allowed us in your crowded columns, we cannot give all the details connected with the facts in our possession. If we could do so, and could illustrate them by maps and diagrams, we could show to the satisfaction of the most obstinate opponent of the jetties that the re-formation of the bar, as prophesied, is a myth. We will briefly allude to the facts and give general results only.

In May, 1875, the United States Coast Survey, under the direction of Mr. H. L. Marindin, one of the most efficient and

careful assistants in the department, made an accurate and detailed survey of the South Pass bar. This survey extended into the Gulf about half a mile from the outer crest of the bar.

In October of this year, (1877,) we made a survey covering the same ground. The lines of soundings were run in the same manner as those of Marindin. The general and detailed plan was similar to his. The work was plotted on the same scale. His soundings were increased by one foot and eight-tenths, to bring his plane of reference up to ours.

The whole area in front of the jetties was then divided into squares of one hundred feet. We took it for granted, that between any two soundings of his and also of ours, the slope was uniform. Depths were thus obtained for each corner of each square.

A skeleton was made, on which these squares were drawn; the calculated depth at each intersection was put down in one color for Marindin's survey, and in another color for ours, and we then had the data carefully arranged for calculations by the prismoidal formula. This plan was adopted on account of the unequal spacing of the soundings and, while it is open to the charge of interpolation, it gives under the circumstances the most accurate results.

The depths having thus been put down, the skeleton was subdivided into larger areas and figures. Using the one thousand feet, between the present end of the jetties, as the base of a rectangle, the jetty lines were produced into the Gulf 2500 feet.

This figure was divided again into smaller rectangles of 1000 feet by 500 feet.

The large rectangle was enlarged by adding 1000 feet to the width at the outer end (500 feet on each side) but retaining nearly the same width at the end of the jetties. Then a larger figure still was drawn in the same way, and so on, until the final figure embraced the fan-shaped area of the discharge of sedimentary matter issuing from the jetties during high river.

The calculations show that over the rectangle (1000 feet by 500 feet) lying immediately in front of the jetties and adjacent to their ends, there has been

an average deepening of four feet and two inches.

This is the identical ground over which the bar re-formation was to take place so rapidly. The rectangle first spoken of, namely, 1000 feet by 2500 feet, we will call A; the next larger figure B, the next C, and so on, each one embracing all the preceding. The result of these calculations is given in the following table :

Letter of Combination.	Area of Combination in square feet.	Mean gain in depth on Combination since May, 1875, in feet.	Quantity of material scoured in Combination since May, 1875, in cubic yards.
A . . . . .	2,500,000	0.878	81,341
B . . . . .	4,000,000	0.727	107,690
C . . . . .	5,300,000	0.996	195,609
D . . . . .	6,520,000	1.144	276,328
E . . . . .	7,770,000	1.166	335,572

A map exhibiting graphically the changes that have taken place, shows clearly that there are well defined areas of scour entirely across the whole mile and a half investigated, and at right angles to the end of the jetties.

We do not need to go beyond this map to prove the existence of a well marked and almost constant littoral or shore current of salt water, sweeping under the fresh water, and not only carrying to one side the vast amount of sediment thrown out of the jetties, but even digging down and cutting into and carrying off much of the original outer slope of the bar.

The surveys and calculations made recently by Capt. M. R. Brown, U. S. Engineers, who is detailed by the Secretary of War to inspect the jetties for the Government, corroborate the statements we have made.

In his report of July, 1877, to the Secretary of War, he compares his survey of June, 1876, with that of June 1877.

We quote some passages that refer to this special subject, and which are found in pages 26, 27 and 28 :

"On sheet No. 4 will be found the results of a survey, in June 20th, to June 22d 1877, of a mile or more beyond the

ends of the jetties, and for a considerable space on either side."

"The subject of fill and scour beyond the ends of the jetties has occupied so much attention that I have carefully compared the results of the survey of June, 1876, with that of June, 1877, and for the purpose have divided the whole area, comparable by means of the two charts, into twenty-one divisions."

"The fan-shaped areas are, of course, those of the most pressing interest when investigating the influences of changes in the immediate future of commerce."

"Taking into account all the divisions except 1, 7, 13 and 21, we find that the scour in the year was 1,145,976 cubic yards, equivalent to a scour of 1 3109-10,000th feet, or 1 foot, 3.7 inches over this latter area."

## MAINTENANCE OF THE PAVEMENTS IN PARIS.

Translated from "Annales des Ponts et Chaussées."

For cleaning streets, machine sweepers are employed drawn by a single horse, cleaning about 5,000 square meters an hour.

The cost of keeping in repair is quite different for the different avenues; for the Rue Lafayette it is 16.08 francs.

The asphalt roadways have a joint area of 225,120 square meters, to which should be added about 34,000 square meters for the walks through the Macadamized streets. The price of construction varies from twelve to fifteen francs per square meter.

The repairing done by contract for 1.10 francs per square meter per year for the roadways, and 1.70 francs for the walks.

The mean cost of repairing roadways in Paris, which was 1.08 francs in 1870, has been reduced to 0.82 francs. This reduction is due especially to a change in many places from Macadam to paved roadways. The mean cost of repairing pavement never exceeds 0.60 franc, while Macadam roadways cost 1.80 francs per square meter. The latter should therefore be replaced, except where they serve as promenades and ornaments, as in the boulevards and avenues.

The following estimates are extracted from a recent report to the Municipal Council of Paris by M. Watel.

The number of vehicles which pass daily through some of the principal thoroughfares of the city have been ascertained to be as follows:

Boulevard de Sebastopol.....	11,602
Avenue des Champs Elysees...	11,734

Rue de Rivoli.....	13,898
Rue Royale.....	16,177
Boulevard des Capucines.....	19,043

The paved roadways have an aggregate total area of 5,458,000 square meters; their maintenance requires the constant service of 431 men (*cantonniers*). The cost per square meter varies from 15.90 francs to 20.40 francs according to the gauge (.10 to .16 meter).

The cost of hand labor in keeping the pavements in order is 0.154 francs per square meter.

The Macadamized roadways cover an area which, although less than in 1870, is still 1,900,000 square meters. The number of *cantonniers* required for their maintenance is 965.

The steam rollers employed weigh about thirty tons each. The rolling is generally completed in a single night.

THE statistics of the loss of human life in the mining of anthracite coal, as gathered by the Pennsylvania mine inspectors, show the following results:—In Shamokin district, ratio of coal produced per life lost, 86,711; in lower Schuylkill district, 107,078; in southern district of Luzerne and carbon counties, 94,679; in middle district of Luzerne and carbon counties, 83,916; in Wyoming Eastern district, 110,511; average, 96,579; in English bituminous mines, 1875, 118,730; in Nova Scotia mines, 1874, 135,063; in Ohio mines, 1875, 142,352; average in Pennsylvania, anthracite mines, 1875, 92,437.

# FORCE, MOMENTUM AND VIS VIVA.

By DE VOLSON WOOD, C. E., M. A.

Written for VAN NOSTRAND'S MAGAZINE.

VOLUMES have been written upon the subjects which head this article, and probably nothing new remains to be said in regard to them. But these pages bear evidence to the fact that writers still differ in regard to their essential meaning, or at least, in regard to their true measure, and it is the privilege of each to defend his position, although he may use arguments that are well nigh worn out.

There are two ways of considering these quantities; one in the light of analysis, and the other in the light of physics; but the results of both, if correct, must necessarily agree. There is an advantage in considering them analytically; for if the equations which represent the quantities are proved and accepted, we have a sure foundation on which to stand, and if any discrepancy between them and observed phenomenon appears to arise we may be certain that our conception of the physical part is incorrect.

All that is necessary to be said in explaining these quantities may be said in a few words. Discussions in regard to them are prolonged because attempts are made to apply them to a great variety of cases, and to give special explanations for each case. We know force only by its effects. Laplace says "The nature of that singular modification, by which a body is transported from one place to another, is now, and always will be, unknown; it is denoted by the name of *Force*." Gravity is one of the forces of nature. If we attempt to hold a body at rest against its action, we experience a pull equal to the weight of the body. If the body is permitted to fall freely, it will have a certain definite acceleration. Here are two distinct results, which give rise to two distinct measures of the same cause. Let any other force, as the pull of a horse, or the force of electricity, act upon a body, it will exert a certain definite pull if the body be prevented from moving, or, if the body be left free to move this force will produce a certain definite acceleration during each instant of its action.

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I will use the term *pull* or pressure in a general sense. Let  $W$  be the measure of the pull of gravity upon a body, and  $g$  the acceleration which it produces in a second of time; similarly let  $F$  be the constant pull exerted by any other force upon the same body, and  $f$  the acceleration per second which it would produce upon the same body if perfectly free to move under its action. The ratio of these pulls we assume to be the same as the ratio of their accelerations, for like causes produce like effects, and hence we at once have

$$\frac{F}{W} = \frac{f}{g} \quad \dots \quad (1)$$

This is the *fundamental* equation of dynamical science, and all other equations of direct motion follow from it. Each member of this equation is an abstract quantity. We may operate upon it algebraically, but having changed its form, and hence the relation of the parts to each other, it will remain to give a proper interpretation to the resulting equation. First, then, find the value of  $F$ . We have at once

$$F = W \frac{f}{g} \quad \dots \quad (2)$$

But the members are no longer abstract quantities. The left member as we said at the outset represents the pull, which we will for convenience call *pounds*. The first member being pounds the second member must also be pounds; or since  $W$ , in the second member is pounds, and  $\frac{f}{g}$  is an abstract quantity, the second member must be pounds, and hence the first member must also be of the same denomination.

But another transformation gives us

$$F = \frac{W}{g} f,$$

in which  $\frac{W}{g}$  is called the mass,—or the measure of the mass of a body whose weight is  $W$  at a place where the acceleration due to gravity is  $g$ , and is repre-

sented by  $M$ . The quantity  $M$  is the  $g^{\text{th}}$  part of the weight of the body. The equation now becomes

$$F = Mf, \quad . \quad . \quad . \quad (3)$$

In this equation the first member is the statical measure of a force; the second member the dynamical measure. The first member is *pounds*, the second member is an equivalent measure of these pounds. The second member has been called by Gauss *the absolute measure of force*, and it is often called by that name at the present time. It is not necessary that it should have a name, but it is quite proper that it should have one. I see that Professor Skinner, in the preceding volume of this Magazine, page 422, proposes to call it *tend*. I trust that the *tendency* will be to oppose the introduction of such technical names unless they are absolutely necessary. If the three names at the head of this article have caused discussions for two centuries or so, and, as is now admitted, are not yet fully understood, what would become of the science of mechanics if three more abstract terms were introduced! Professor Skinner also remarks on the same page that "As to practical convenience there may sometimes be advantage in using this unit of force." Now I remark that it is absolutely necessary that it (the absolute unit) should be used. Were we unable to measure the pounds of pressure (or pull) which produces motion in a body by the elements which enter into that motion, Dynamics would be a 'sickly science, if indeed it could exist as such. Whether we give a name to the second member of equation (3), or not, the fact that *the mass of a body into its acceleration measures at each instant the pounds pressure exerted upon a body*, enables us to establish an equation—a fundamental equation—from which all others in regard to motion, work and momentum are derived. These equations are, 1st :

$$F = M \frac{d^2s}{dt^2};$$

multiplying by  $dt$  and integrating and we have a second, or

$$\int F dt = M \frac{ds}{dt} = MV;$$

or, multiplying by  $ds$ , we have the third, or

$$\int F ds = \frac{1}{2} M \frac{ds^2}{dt^2} = \frac{1}{2} M V^2,$$

An interpretation of these equations, covers the whole ground of the controversy. But, in order to present this subject without the use of the Calculus, we will consider *constant* forces. It has been proved by Atwood's machine (or in some other way) that

$$f = \frac{V}{t},$$

in which  $V$  is the velocity produced in a time  $t$  by a constant acceleration  $f$ . Substituting this value in equation (3) gives

$$F = M \frac{V}{t},$$

or

$$Ft = MV. \quad . \quad . \quad . \quad (4)$$

The second member of this equation is called *momentum*. But what does that mean? What is its office? What is its function in the physical world? We will answer these questions affirmatively and negatively, and somewhat in detail.

1st. Its office cannot be determined from its name. That may be used as a mere convenience. It may be a name given to the product  $MV$ ; or to an effect produced. If the latter, what effect?

2d. It cannot be determined from the product  $MV$ . A body whose mass is  $M$  may have a velocity  $V$ , but we cannot tell what function the product of these quantities is without considering what produces the effect.

3d. Its office can be determined only in connection with the first number of equation (4). From that we find, that

4th. *It is the measure of the effect of a moving force  $F$  acting upon a body during a time  $t$ .* For the sake of brevity I call this a *time-effect*, a term which is partly descriptive of the first member of the equation. This effect is independent of the space passed over, except that space is implicitly involved in velocity.

5th. It is not the measure of force.

6th. Momentum may be made to measure a force—numerically. Observe, I do not here say the momentum of the body, but, as will soon appear a certain momentum, a restricted momentum.

Some of these statements admit of further explanations. By moving force I mean that part of the acting forces

which produce motion only. Thus a body is acted upon by a constant pull, but there may be resistances of friction, or of the air, or the motion may be opposed by a pull in the opposite direction. If the force which produces motion only be removed, all the other forces will be in equilibrium. If all the forces which are in equilibrium among themselves be removed, then will the measure of the *time-effect* of the remaining force be the momentum. But just here we meet an objection by Professor Skinner, in the preceding volume of this Magazine, page 426, where it is claimed that "Writers have generally agreed to measure the *effect* of a force by work." I confess that I am ignorant of such an agreement. They say, at the outset, that *force is measured by its effects*. What are its effects? One of its effects is to produce pressure between two bodies; another is to produce motion; another, to do work; another, to produce energy; another, to produce tension in elastic bodies. That writer further adds: "It seems to me that we need in mechanics a name which shall apply to the *exertions of a force during time*, whether this produces apparent motion of masses or not," and suggests the word *toil*. First, I inquire, what is meant by a force acting during time without producing motion. Is mere pressure exerted during time anything but pressure? Remove this ambiguity from the condition, and the propriety of adopting the same term as the one commonly used, will be apparent. I refer to the well-known term *Momentum*. The proposed *toil* can find no place in mechanics without expelling the present occupant.

I am unable to determine Professor Skinner's position. For instance, on page 128 of the preceding volume, in regard to the unit of momentum, he raises the question, "If a body equal to 10 units of mass have a velocity of 10 feet per second, its momentum will be equal to  $10 \times 10 = 100$ . But 100 what? If *momentum is quantity of motion* it certainly cannot be 100 pounds, and it is quite as difficult to say that this body has a *quantity of motion* equal to 100 feet." But on page 132 he says: "The unit of *momentum*, then, is a force of pressure equal to one pound." I supposed that

this was an over-sight, but I find on page 133 the following: "we saw that momentum, which is equal to  $MV$ , represents the number of pounds pressure which the mass  $M$  with the velocity  $V$  is capable of exerting under a certain arbitrary condition." Here the mass, or body not the force, exerts a pressure, and it equals a certain number of pounds; but this position appears to be demolished in his article in the October number of the Magazine, pages 321-327. Again, on page 235, we find "its momentum will be  $1441\frac{2}{3}$  pounds;" on page 237, "You may say, if you please, that it has a negative momentum equal to  $441\frac{2}{3}$  pounds;" page 240, "We have seen, first, that the unit of momentum is simply a pound pressure, a unit which does not include the idea of motion"! From these and several other expressions, I would infer that Professor Skinner claims that momentum is pounds of pressure. But, on the contrary, we find on page 130 and in several other places it is explicitly stated that momentum is the pounds of pressure which, *acting during one second*, in an opposite direction to the motion, will bring the body to rest. If time, or the unit of time, is essential to momentum, then *the idea of motion* is involved. But, if the last definition is the correct one, what difficulty has been removed? It is simply equivalent to assuming that one momentum equals another momentum, or

$$Ft = F. 1 \text{ sec.} = MV, \quad (5)$$

which is evidently correct, but, I repeat, what difficulty has been removed, or what essential principle explained? The physical quality of momentum is exactly the same as before and equally obscure; if, indeed, there is any obscurity about it. The fourth principle given above, states exactly what it is and, we hope, without ambiguity. Still, one or two remarks more in regard to it may be proper. If only a single force acts upon a body, the body must be—indeed it will be—perfectly free to move, and the relation

$$Ft = MV$$

will constantly be true. But a body, acted upon by pulling and resisting forces may move at an uniform rate; in which case the product  $Ft$  has no meaning during such uniform motion.

In regard to the unit of momentum, it may be determined from either member of equation (4). In the second member, if the unit of mass is one pound of mass, and the velocity one foot per second, then *the unit of momentum will be one pound of mass moving with a velocity of one foot per second.* Or, if a compound word be used, as is done in the case of work (I refer to "foot-pound") we would have, (*mass-pound*) (*velocity-unit*). This is sufficiently awkward to explain why such a term has not been used, if any explanation were necessary, and I have given it only for the purpose of making it correspond in form with the work-unit. But we may deduce the unit from the first member of the equation, as is done in the equation between work and energy. If  $F$  be pounds of pressure, and  $t$  seconds of time, then will the unit be *one pound pressure acting during one second*; or, adopting the compound word as before, we have for the unit a *pound-second*.

The fifth statement above, asserts that momentum is not the measure of force. To show this it is only necessary to observe, that solving equation (4) gives

$$F = \frac{MV}{t},$$

from which it appears that it is necessary to divide the momentum by the time in order to find the value of the force. But the quotient obtained by dividing the momentum by time is not momentum, but pounds, or its equivalent. We say, therefore, that *momentum never measures force.*

But if, in the preceding equation,  $t$  is unity, one second say, and the velocity generated in one second be denoted by  $V_1$ , we have .

$$F = \frac{MV}{1 \text{ sec.}} = MV_1 \text{ numerically;}$$

hence, a simple interpretation of the formula gives

*The measure of a constant force is numerically equal to the momentum which it is capable of producing in a free body in a unit of time.*

The word *numerically* is ordinarily omitted in this rule, but we are seeking to preserve the exact relations of the quantities.

If *numerically* is omitted it should

read *the mass into the acceleration, instead of the mass into the velocity per unit of time.*

It is well to observe that, when the force is constant  $V \div 1 \text{ sec.}$  is the acceleration, in other words, the velocity produced in one second equals (numerically) the constant acceleration. Calling this  $f$  and we have

$$F = Mf$$

which is equation (3).

If the force be constantly varying, but of such intensity that it would produce a velocity of  $V_2$  in one second provided its intensity did not change, then we have

$$F = M \frac{dV}{dt} = M \frac{V_2}{1 \text{ sec.}}; \quad (6)$$

that is, *the measure of the intensity of any force at any instant is numerically the momentum which it is capable of producing in a free mass in a second of time.*

Observe, that the measure is not the momentum which the body has, but the momentum added to (or taken from) the body each instant that is the numerical measure.

Equation (6) also shows that the measure of a force is the rate of change of the momentum of a body. Since this expression has been criticised by Professor Skinner I emphasize, by stating that it is not merely the *numerical* but the *actual* measure. Rate is not an abstract ratio. The expression  $\frac{dV}{dt}$  is the acceleration, which we have represented by  $f$ , hence equation (6) becomes  $F = Mf$  which again is equation (3).

Momentum is frequently defined as *quantity of motion*. To this, objection is made by Professor Skinner in his articles in the preceding volume, pages 136, 235, &c. Without following this writer through all his examples and arguments, we observe that there are some illustrations on page 235 which are so liable to mislead, that the errors ought to be corrected, and when corrected, will leave his position in regard to positive and negative momenta, without foundation. That writer desires to show, if I understand him, that momentum must always be considered as positive,—that there is no negative momentum. To do this, he

shows how a momentum which is considered negative may be changed to a positive one. He says, page 235, "Besides there are many ways in which the direction of motion may be changed without material loss of velocity. Suppose the mass  $M$  after the recoil (it was supposed that the mass  $M$  had struck another body and recoiled) to strike perpendicularly a fixed elastic spring. It will be thrown back again in the direction of the first motion with a little loss of velocity." For the sake of the argument, suppose that there is no loss of velocity. Then, in this new condition, he says (correctly) that the total momentum is the sum of the two momenta; the negative having been changed to positive. But where can a *fixed* spring be found? Rest the spring against the solid earth, if you please, and will no effect be produced upon the earth by the impact of the body upon the spring? Will not that writer's own reasoning show that the momentum imparted to the earth will be twice that of the ball thrown back, and thus the total momentum of the two masses *plus* that of the earth be the same as that of the two balls immediately after impact? They certainly will. The same result will be true of the semicircular arc which he uses. In the use of the inclined plane the momentum has been first overcome by the force of gravity, and then again restored to it during the descent. Or, in the case supposed, page 235, in which the bodies are supposed to raise vertically other weights, if the motions be traced out it will be found that everything is consistent with the algebraic idea of *plus* and *minus* momenta. He remarks on page 237 "We need not be afraid of the fact that it is possible to have an actual increase of momentum by impact." Still, I confess, we are afraid!

Now the expression *quantity of motion* may not be the best, it may even be unfortunate, but it is not necessarily false. The meaning intended to be conveyed by it may be explained just as well as if any other term were used,—as *toil* for instance. The effect of a force, acting on a free body, is to produce motion. Here motion is used in a general sense. The *rate* of motion is velocity. The *quantity* of motion is momentum. There is a wide distinction be-

tween *rate* and *quantity*. At least one English writer says momentum is *quantity of Velocity*. This, I consider, is false. Quantity of rate is absurd. We might as well say quantity of foot, quantity of minute, &c. One of the elements which enters into the measure of the motion is velocity, and the other is mass. We say in the abstract that a given force produces a definite amount of motion, but this force acting on a small mass will produce a greater velocity than if applied to a large mass. Different forces will produce different amounts of motion, that is to say different quantities of motion. We say that the intensity of heat is the amount of heat in a unit of volume, but the quantity of heat is the total heat in the body; the intensity of light is the amount of light on a unit of area, but the quantity of light is the total amount on the whole area; the intensity of gravity is the acceleration it will produce on a unit of mass, but the quantity of gravity is the total force on the body, or  $W = Mg$ . So the intensity of the motion is the velocity,  $V$ , and the quantity of motion is  $MV$ .

In regard to this subject the writer was criticised by Professor Raymond of West Point, in his caustic review of the writer's work on Analytical Mechanics, but these need not be considered here as I made a somewhat extended reply to them in the *Mining and Engineering Journal* of June 9th of the present year.

We now make another modification in equation (3). By means of Atwood's machine, or in some other way, it has been proved, that, for constant forces producing motion, we have

$$f = \frac{V^2}{2S}$$

in which  $V$  is the velocity produced in a space  $S$ . Substitute this in equation (3), and we have

$$F = \frac{1}{2} M \frac{V^2}{S};$$

hence, multiplying by  $S$ , we have

$$FS = \frac{1}{2} M V^2 \quad . \quad . \quad . \quad (7)$$

We now proceed to interpret this result. The first member is evident. It is the product of the constant force by the space over which it acts, and may be called briefly *space-effect*. What is the second member? We say here, as we

said in regard to momentum, that it cannot be determined by itself; it can be determined only in connection with the first member, or that member which contains the value of the force. Both members of this equation have received appropriate names. The first member is called *work*, the second, *energy*, not *potential energy*, as stated in the last lines of page 240 of the preceding volume, but *kinetic energy*. The first member is the work which the force  $F$  does in having its point of application moved over a space  $s$  in the direction of action of the force. The second member is the energy of the mass  $M$ . The energy of a body therefore, equals a *space-effect*. It equals a certain amount of work. It is stored work.

The expression for work in mechanics is derived from, or is the same as, the expression for physical work. A force may work without producing energy\*. Thus, a horse, drawing a load at a uniform rate does work but produces no energy. The same is true of a locomotive drawing a train at a uniform rate. If a resistance  $F$  has been overcome through a space  $s$  work has been done regardless of the time occupied in overcoming it. Here we see an essential difference between the first members of the equations for momentum and energy. If a body has been dragged from one point directly to another, a certain amount of work has been done. Suppose, now, that we see the body in the first position on a certain day, and in the second position at any subsequent time, and that we know the resistance  $F$  which must be constantly overcome to move the body. Then will  $F$ 's have a well-known meaning, but  $Ft$  will be meaningless. The mere lapse of time accomplishes nothing. Will those who seek a common unit between work and momentum (and there are many such) show *any* connection between  $F$ 's and  $Ft$  in the above example? If the time occupied in moving the body were known, the product  $Ft$  would still have no rational meaning. Hence it is, that work is truly said to be independent of the time. If the *rate* of working be given, then time becomes as important an element as space.

When quantities differ in any essential

quality, they cannot have a common unit. There is no unit common to a line and an area; or an area and a surface; or time and space; or force and momentum; or momentum and vis viva. Each must have its own unit which is necessarily some definite part of the quantity to be measured. The *pound-second* and the *foot-pound* are as unlike as the linear foot and the square foot.

We observe, further, that equations (4) and (7) are deduced on the hypothesis that the body upon which the force acts is free to move; or, what is the same thing, that the second members of those equations expresses in terms of mass and velocity, the effect of the unbalanced forces acting on the body; the former expressing the effect produced in a time  $t$  and the latter in a space  $s$ ; also that the first member of equation (4) has no meaning unless the force acts on a free body, but the first member of equation (7) has two significations, one when the force acts upon a free body producing energy, the other, when it is constantly overcoming a resistance along its path. The latter, we might call *dead work*—work accomplished; the former *live work*—work which the body is yet capable of doing. Hence it is, that momentum pertains *only* to the motion of bodies, but energy both to motion and resistance. The former, therefore, for a system of bodies moving without external forces but with mutual actions, *must* be constant; and this explains why I am afraid to have an increase of momentum by impact. But the energy of a body may be expended in producing (or imparting) energy in another body, or in overcoming resistance, or, as in the case of non-elastic impact, both at the same time. Momentum is not lost, hence cannot be conserved (or in a mathematical sense is perfectly conserved), but energy, in any particular form, may be lost and hence the importance of proving that it may be conserved; that is, that in all its transmutations, nothing is lost.

In passing we note, by way of analogy, that in the transmutation of momentum, it is always transmuted (strictly speaking *transmitted*) from one mass to another. It is a molar transmutation; but in the case of energy, the transmutation may be into heat, electricity, &c.

But right here, John, who has been

\* Mass energy is here referred to. The heat energy developed by friction is discarded in this discussion.

very patient up to this point, rises in his place and asks; When a problem is assigned, how shall we know which principle to use in its solution? We answer that the problem may require the use of neither, or both may be involved. If the problem is the case of the impact of free bodies, and the resulting motion is required, the problem will be solved by the principles of momentum. For, the action and reaction between the bodies during impact will act *during the same time*. They will not (generally) act through the same space. If the resulting energy is required then the principle of energy must be used in addition to that of momentum. If the body struck be held or opposed by other forces, like an anvil, resting on the earth, or a pile driven into the ground, then nothing will be determined by momentum.

Energy is essentially positive, for if the velocity be positive or negative, the expression  $\frac{1}{2}MV^2$  is essentially positive; but momentum may be positive or negative since  $V$  may be *plus* or *minus*. It is an interesting fact that the first members of the equations lead to the same result. If a force in one direction be considered positive and the opposite direction negative, then will  $Ft$  be of the same sign as  $F$ , for an action cannot proceed in negative time. Time is progressive and cannot be reversed during an action. But space may be either *plus* or *minus*, and hence we have.

$$(\pm F) \times (\pm s) = +Fs = \frac{1}{2}MV^2.$$

*Energy may numerically measure a force.* Deducing the value of  $F$  from our equation we have

$$F = \frac{1}{2}M \frac{V^2}{s}.$$

Let the force act during one foot on a free body, producing a velocity  $V$ , then we have

$$F = \frac{1}{2}M \frac{V^2}{1 \text{ ft.}} = \frac{1}{2}MV^2, \text{ numerically;}$$

hence, *the measure of the intensity of a constant force is numerically the energy it will produce while acting through one foot of space.*

But it is proved by Atwood's machine, or otherwise, that for a constant acceleration

$$f = \frac{V^2}{2s}$$

which substituted in the preceding equation gives

$$F = Mf$$

which is equation (3) and hence no new fact has been stated by the preceding conclusion. If the force be variable, we have, by differentiating both sides of the equation,

$$Fds = \frac{1}{2}Md(V^2),$$

$$F = \frac{1}{2}M \frac{d(V^2)}{ds}; \quad . \quad . \quad (8)$$

that is, *the measure of any force is numerically the energy that it would develop in a unit of space, if the force acted during that unit with a constant intensity.*

But this conclusion leads to no new fact. For differentiating  $V^2$  gives

$$d(V^2) = 2VdV$$

and, by substituting the value of  $V$  we have

$$\frac{d(V^2)}{ds} = 2 \frac{d^2s}{dt^2},$$

and, by substituting this in the preceding equation and reducing, we have

$$F = M \frac{d^2s}{dt^2}, \quad . \quad . \quad . \quad (9)$$

which is equation (3).

Equation (8) also shows that the measure of a force is the rate of change of the energy (or vis viva) of a body per foot of distance. But this is merely equation (3) under another form, as shown by the preceding reduction, and that may be reduced to equation (1). All our results, therefore, flow from equation (1), or may be traced back to that equation.

We therefore conclude, that, in accordance with strict technical language, *neither the momentum of a body nor its energy is a measure of the force which acted upon it.* Or, more generally, *that neither momentum nor energy is the measure of force.*

Also, *that the momentum which a force would generate in a unit of time if acting constantly upon a free body; or the energy which the force would develop in a unit of space if acting constantly upon a free body; either of these is NUMERICALLY equal to the pounds of force which produces the motion.*

Also, *that neither the momentum of a body, nor its energy is a measure NUMERI-*

*CALLY of the generating force, unless the body starts from rest, and in the former case the action is for one second of time, in the latter for one foot of space; the units being assumed as a second and a foot. Also, that the pound pressure or its equivalent is the universal measure of force.*

When there is a clear conception of the true measures of these quantities, such meaningless expressions as: the force of momentum; the force of energy; the force of a blow; the quantity of force in a moving body; the energy corresponding to a force; and the like, will disappear.

## THE DIRECT PROCESS IN THE PRODUCTION OF IRON AND STEEL.\*

By C. W. SIEMENS.\*

From "Journal of the Society of Arts."

IN mixing comparatively rich iron ore in powder, with about twenty-five per cent. of its weight of pounded coal, and in exposing this mixture for some hours to the heat of a common stove or of a smith's fire, metallic iron is formed, which, on being heated to the welding point, on the same smith's hearth, may be forged into a horse-shoe of excellent quality. The admixture with the ore of some fluxing materials, such as lime or clay, will, in most cases, be of advantage to rid the iron of adherent slag.

The simplicity of this process is such that it naturally preceded the elaborate processes now in use for the production of iron and steel upon a gigantic scale; nor can it surprise us to find that attempts have been made from time to time, down to the present day, to revert to the ancient and more simple method. It can be shown that iron produced by direct process is almost chemically pure, although the ores and reducing agent employed may have contained a considerable percentage of phosphorus, sulphur, and silicon, and that, if freed from its adherent slag, it furnishes a material superior in quality and commercial value to the ordinary iron of commerce.

The practical objections to the direct process, as practised in former days, and as still used to a limited extent in the United States of America and in some European countries, are that—

1. Very rich ores only are applicable, of which about one-half is converted

into iron, the remainder being lost in forming slag.

2. The fuel used is charcoal, of which between three and four tons are used in producing one ton of hammered blooms.

3. Expenditure of labor is great, being at the rate of 33 men, working 12 hours, in producing one ton of metal (see Percy). Iron produced by direct process in the Catalan forge is, therefore, expensive iron, and could not compete with iron produced by modern processes except for special purposes, such as furnishing melting material for the tool steel melter.

But, it may be asked, could the advantages of the direct process not be combined with those of modern appliances for the production of pure and intense heats, and for dealing with materials in large masses, without expenditure of manual labor, and cannot chemistry help us to larger yields and the faculty of using comparatively poor and impure ores?

A careful consideration of these questions led me to the conclusion, some years ago, that here was a promising field for the experimental metallurgist, and that I possessed some advantage over others in the use of the regenerative gas furnace as a means of producing the requisite quantity of heat without the use of charcoal and blowing apparatus. I engaged, accordingly, upon a series of experimental researches at my sample steel works, at Birmingham, and, in 1873, I had the honor of submitting the first fruits of these inquiries to the Iron and

\* Paper read at the Newcastle meeting of the Iron and Steel Institute.

Steel Institute, in a paper entitled "On the Manufacture of Iron and Steel by Direct Process." Encouraged by the results I had then obtained, I ventured with some others upon some larger applications, the principal one of which has been one at Towcester, in Northamptonshire.

Viewed by the light of present experience, it would have been wiser to have fixed upon another locality, with fuel, skilled labor, and better ores within easy reach; but, in extenuation of the error committed, it may be urged that the site was fixed by force of circumstances rather than by selection, the chief temptation being an ample supply of small Northamptonshire ore at a very low cost. It was, however, soon discovered that this ore, although capable of producing iron of good quality, was too poor and irregular in quality to yield commercial results unless it was mixed with an equal weight of rich ore, such as potter mine, Spanish ore, or roll-scale, all of which, as well as the fuel, are expensive at Towcester, owing to high rates of carriage. It is in consequence of these untoward circumstances that the works at Towcester have not been completed by the addition of rolling mills, the intention being to transfer the special machinery ultimately to existing ironworks when the process has been sufficiently matured for that purpose.

The Towcester Works were visited, in the autumn of last year, by two eminent metallurgists, Professors von Tunner, of Leoban, and Akermann, of Sweden, who have published the results of their observations in separate reports. The results noted down by Mr. von Tunner are referred to by our past president, Mr. I. Lowthian Bell, in his paper on the "Separation of Carbon, &c.," which was read in March last, and will be discussed at the Newcastle meeting. The criticisms contained in these publications are conceived in the fairest possible spirit, and form indeed a most valuable record of the progress achieved up to that time, but they furnish me with an inducement to break silence sooner than I had intended, regarding the further progress which has been effected, and the conclusions I am disposed to draw from past experience regarding the direct process of the future.

The leading idea which guided me in these was to operate upon such mixtures of ores, fluxes, and reducing agents, as would, under the influence of intense heat, resolve themselves forthwith into metallic iron and a fluid cinder, differing essentially from the methods pursued by Chenat, Guilt, Blair, and others, who prepare spongy metal in the first place by a slow process, which is condensed into malleable iron or steel by after-processes, but assimilating to some extent to the process first proposed by Mr. William Clay. In my paper of 1873 I described two methods of effecting my purpose, the one by means of a stationary, and the other by means of a rotative furnace chamber, the former being applicable chiefly where comparatively rich ores are available, and the latter for such poorer ores as occur near Towcester.

At the Towcester Works three rotative furnaces have been erected, two of them with working drums, 7 feet in diameter and 9 feet in length, and the third of smaller dimensions. The gas flame both enters and passes away from the back end of the furnace, leaving the front end available for the furnace door, which is stationary. The ends of the furnace-chamber are lined with Bauxite bricks, and the circumference with ferrous oxides, resulting from a mixture of furnace cinder enriched with roll scale or calcined blackband in lumps. About 30 cwt. of ore, mixed with about 9 cwt. of small coal, having been charged into the furnace, it is made to rotate slowly for about two and a half hours, by which time the reduction of the metal should be completed, and a fluxed slag be formed of the earthly constituents containing a considerable percentage of ferrous oxide. The slag having been tapped, the heat of the furnace and the speed of rotation are increased to facilitate the formation of balls, which are in due course taken and treated in the manner to be presently described.

These balls contain on an average seventy per cent. metallic iron, and thirty per cent. of cinder, and, upon careful analysis, it is found that the particles of iron, if entirely separated from the slag, are pure metal, although the slag may contain as much as six per cent. and more of phosphoric acid, and

from one to two per cent of sulphur. In shingling those balls in the usual manner the bulk of the cinder is removed, but a sufficient residue remains to impart to the fracture a dark appearance without a sign of crystalline fracture. The metal shows, in being worked, what appears to be red shortness, but what should be termed slag shortness. In re-piling and re-heating this iron several times this defective appearance is gradually removed, and crystalline iron of great purity and toughness is produced; but a more ready mode of treatment was suggested by Mr. Samuel Lloyd, one of my co-directors in the Towcester Company, in reverting to the ancient refinery or charcoal hearth. The balls, as they came from the rotator, are placed under the shingling hammer, and beaten out into flat cakes not exceeding an inch in thickness. These are cut by shears into pieces of suitable size, and formed into blooms of about 2 cwt. each, which are consolidated under a shingling hammer and rolled into bars.

The bars have been sold in Staffordshire and Sheffield at prices varying from £7 to £9 per ton, being deemed equal to Swedish bar as regards toughness and purity.

It may therefore be asserted, as a matter of fact, that iron and steel of very high quality may be produced from ores not superior to Cleveland ores by direct process, but the question remains at what cost this conversion can be effected. The experimental works at Towcester are, unfortunately, not sufficiently complete to furnish more than the elements upon which the question of cost may be determined, the principal reasons being that the one reheating furnace and a 30 cwt. hammer at the works are not sufficient to deal with the iron produced by the three rotators, that the iron has to be finished at a rolling-mill elsewhere, and that transports weigh heavily upon the cost of production. The principal factor in the calculation of cost is unquestionably the rotator. [A table furnishes the working result of eighteen consecutive charges as taken from the charge-book.] The mixture of ore consisted, for each charge, of 12 cwt. of Towcester ore (containing about 38 per cent. metallic iron) mixed with 8 cwt. of

calcined Great Fenton ore, 1 cwt. of tap cinder, 1 cwt. of limestone, and  $6\frac{1}{2}$  cwt. of small coal. The time occupied for each charge was three hours fifty-seven minutes, or, say four hours, and the yield of hammered blooms was on an average 6 cwt. 2 qrs. 13 lbs., whereas the metal contained in each charge amounted (by estimate) to 9 cwt., showing a loss of 25 per cent. This loss is, however, partially recovered in using a portion of the cinder again in succeeding charges, but the portion of cinder that may be used again with impunity depends upon the amount of impurities, namely, of phosphorus, sulphur, and alumina contained in the ore. The coal used in the producers amounted to two tons per ton of hammered blooms produced, and in pricing the materials used, and labor engaged upon the work, the table—prepared by the manager at the works—gives £3 8s. as the cost per ton of hammered blooms. To this must be added for repairs and general expenses, and the cost of rolling the hammered blooms into bars, which in the case of Towcester practice are very heavy, but of which an experienced iron-master would form his own estimate. The cost of working the metal in the hollow fires is also not included, and this may be taken to add from 25s. to 30s. to the ton. The refined iron so produced will, therefore, cost from £5 5s. to £5 10s. per ton.

Other tables give the analysis of irons produced from various descriptions of ores, and Kirkaldy's tests of the mechanical properties of the iron; but it should be understood that these tests were taken with a view rather to test various modes of manufacture than to show high results. Only a small proportion of the samples had been subjected to the refinery process, and the variable percentage of phosphorus may be taken really as indicative of the extent to which the cinder had been removed from the metal.

Another table gives the analysis of slags produced in the process. These are, no doubt, rich in iron, but it must be remembered that in the case of comparatively pure ore, they can be used almost entirely in succeeding charges, and that in the case of ores containing much sulphur and phosphorus, they are the recipients of those impurities—in the same

way as the puddling cinder carries off the same impurities in the puddling furnace—and thus serve a useful end.

If rich ores, such as hematites, are available, it is more advantageous to use a stationary furnace, and to modify the process as follows :

A mixture of pulverulent ore, mixed with a suitable proportion of fluxing materials and reducing agents, is prepared, and from four to 5 tons of it are charged from a charging platform into the heated chamber to the depth of some 12 to 15 inches. But, before charging the mixture, some coke dust or anthracite powder is spread over the bottom and sides of the chamber to protect the silica lining of the same. The heat of the furnace is thereupon raised to a full welding heat, care being taken that the flame is as little oxidising as possible. The result is a powerful superficial action upon the mixture, or batch, causing simultaneous reduction of the ore and fusion of the earthy constituents. In the course of two hours a thick skin of malleable iron is formed all over the surface of the mixture, which, on being withdrawn by means of hooks, is consolidated and cleared of cinder under a hammer, and rolled out in the same heat into rough sheets of bars, to be cut up and finished in the refinery furnace or charcoal hearth. One skin being removed, the furnace is closed again, and in the course of an hour and a half another skin is formed, which, in its turn, is removed and shingled; and so on, until, after three or four removals, the furnace charge is nearly exhausted. A fresh charge is then added, and the same operation continued. Once every twelve hours the furnace should, however, be cleared entirely, and the furnace lining be repaired all round.

The shingled metal so produced forms an excellent melting material for the open-hearth or Siemens-Martin process; but if ores both rich and free from sulphur and phosphorus are used, together with roll and hammer scale, which forms an admirable admixture, I simplify the process still further in causing the fusion to take place in the reducing furnace.

The furnace having been charged with, say, five tons of batch, the heat is allowed to play on it for four or five hours, when about two tons of hematite

pig iron are charged upon the surface by preference in a heated condition. The pig metal, on melting, constitutes a bath on the surface of the thick metallic skin previously formed, and gradually dissolves it on the surface while it is forming afresh below, and in the course of from three to four hours the whole of the materials charged are rendered fluid, consisting of a metallic bath with a small percentage of carbon, covered with a glassy slag containing about 15 per cent. only of metallic iron. The carbon of the bath is thereupon brought down to the desired point of only about 1 per cent. of carbon, and spiegeleisen or ferro-manganese is added, and the metal tapped in the usual manner. By these means the direct process of making cast steel is carried to a further limit than I have been able to accomplish before, and no difficulty has presented itself in carrying it into effect. The steel so produced is equal in quality to that produced by the open hearth process as now practised. If light scrap, such as iron and steel turnings or sheerings, are available, these may be mixed with advantage with the batch to increase the yield of metal.

These are, in short, the more recent improvements in the direct process of producing an iron and steel which I have been able to effect, and which I should have been glad to lay before the Iron and Steel Institute in a more complete form than I am able to do at the present time.

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THE Health Committee of Glasgow, says the *Analyst*, seems to be going rather ahead of the sanitary boards of other cities, and we think very wisely so. They are carrying on continuous observations, at different stations in the city, on the variations in the composition of the air, and have expended a considerable sum of money in fitting up a laboratory in order to determine the variations which occur from time to time in the composition of the atmosphere itself, and the character of the floating particles which are present in it. The committee certainly deserves the utmost credit for taking a step so far in advance of any which has been taken by any ordinary public body.

## THE REGULATION AND QUALITY OF THE SUPPLY OF FRESH AIR IN VENTILATION.\*

From "The Architect."

IN determining the quantity of air to be supplied to and removed from a building, and adjusting the corresponding capacity of the air-shafts, it is customary to assume standard temperatures of the air inside of the building, and of that outside which must be heated before distribution. The latter is taken as the average winter temperature. The height of the building and of the exhaust shaft being known, it is easy to calculate the approximate sizes of the air-ducts required for the supply and removal of a required quantity of air in a certain time say in cubic feet per minute. But the great range of temperature in our climate, often touching extremes as far as 50° Fah. apart within twenty-four hours, is a sufficient reason for not adopting any such rule, without taking extraordinary precautions. Supposing the flow of air in the shafts on a mild day to be represented by the number 25, the relative flow on a cold day would be 30. Economical considerations require that it should be just the reverse, since more fuel is required, first, to heat the extremely cold air; and second, to heat the increased quantity: which involves a waste amounting to 17 per cent. Then the natural ventilation of the building—that which takes place through its cellar, walls, windows, doors, and roof, which is not taken into account in a scheme of ventilation—is materially increased in cold weather, and a large amount of heat must be expended to meet it. But the greatest obstacle of all is the prevalence of high winds which accompany, or rather bring on, a low temperature.

The force which determines the movement of air in shafts is a very small quantity, being only the difference between the weights of a column of air as high as the exhaust shaft, having the temperature of the outflowing air, and of a similar column having the external temperature. This force is, in most

cases, less than one-hundredth of that of a strong north-west wind.

To counteract the effects of temperature and wind, supposing that there is no force employed except that obtained by heating the foul air in the exhaust shaft, the most careful study and judgment will need to be used in locating the fresh air openings, proportioning and arranging the flues, and in regulating the exhaust. Valves in the inlet shafts are usually employed; and, since appliances to regulate the flow of air under varying conditions must be adopted, it is important that they should be few in number and simple in arrangement. The occupants will be fortunate if the ventilating apparatus of their building receives intelligent and faithful superintendence; and since the design is likely to be defective, and its working vexatious to the best-meaning manager, there is no sense in blaming him for relying upon his own judgment, and securing what seem to him the best possible results. Let there be but one inlet, with a valve to regulate the supply, and a pressure meter to show at a glance the volume admitted per minute; one heating chamber, with an arrangement for adjusting the temperature of the warmed air, an indispensable but never seen appliance; with a thermometer to show the temperature, and a valve in the only outlet shaft, operated from the same point as that in the inlet. With this arrangement only three simple operations are required to regulate the quantity of air and its temperature, and the results of all are immediately manifest. If a mistake is made, it can be instantly corrected, without waiting for complaints from the suffering occupants above, since the engineer sees exactly what he is doing. If he once finds that he can make any required change, his interest and gratification are increased, and he will take a pride in the certainty with which he can secure exactness.

The disposition of details in ventilating work must be directed by experience

\* Paper read at the meeting of the Social Science Association at Saratoga, Sept., 6, 1877, by Mr. Frederic Tudor.

alone. The books on the subject, so far as they give us history and examples, are valuable; but even these are defective, since they seldom give well-observed facts and results. As to the purely theoretical works, they are of no practical value whatever. The formulas which they give are deduced from limited data, derived from the simplest cases. The higher mathematics cannot deal with quantities made up of a large number of variables; and a scheme of ventilation is entirely composed of varying conditions, variously connected and growing out of each other. Mathematical and physical research do give valuable data for use in ventilation, but they do not teach the art, nor do they throw much light upon the more complicated details which are the chief embarrassment of the work. The art of ventilation must be learned like any other art or trade, by practice combined with instruction; and expertness can be acquired by those only who are close observers, who have a certain intuitive judgment, and who have taken time to devote themselves to a thorough practical investigation of the subject.

Much care must be taken to avoid impairing the quality of the supplied fresh air in the process of warming it. The natural purity of the fresh air may be diminished by contact with red hot surfaces of iron, which will extract a portion of its oxygen, especially the oxygen which is united with hydrogen in the form of invisible vapor, whereby the degree of humidity is reduced, and hydrogen set free in the air; which will charge it with the unpleasant gases given off by dust and dirt which have been carried into the heating apparatus from the street, when heated to a high temperature, or by leakage of the products of combustion from the heating apparatus. The healthfulness of the air may be still further reduced by neglecting to add to the amount of its vapor while increasing its temperature. All these evils have been found to exist where furnaces of cast iron are used; and, without considering whether they might be owing to defects of construction, it has been hastily assumed that the material—cast iron—was the cause of them all. The partial investigations of MM. Deville and Troost, undertaken at the instance of Gen. Morin, have been accepted as

finally condemnatory of cast iron as a material for stoves and furnaces. They, in reality, only prove that the apparatus with which they experimented was imperfect in construction, as might be expected in a stove of the cheapest possible character. The competition to sell merchandise, and to buy the cheapest offered, has resulted in the gradual elimination of all qualities of excellence in warming apparatus. As to the diffusion of the poisonous gas—carbonic oxide—through the imaginary pores of cast iron, it amounts to nothing, and can scarcely be detected with the most extreme care, even in air exposed to prolonged contact with the hot iron; but the free passage of this gas through the imperfect joints of the ordinary cheap furnace amounts to a great deal. And all the evils arising from over-heating will certainly be found when the heating surface has been so reduced as to make it necessary to keep it red-hot all the time. It is now generally thought that wrought iron is a more suitable material for furnaces than cast iron. This is true, but is no new discovery. The objection to it has always been the great cost of working it; and, in order to compete with cast iron furnaces of good quality, the makers have been compelled to omit the best features, and admit defects which make them in every way inferior to an old-fashioned, honestly-built, cast iron furnace. A good wrought iron furnace cannot be cheap; its cost should be certainly double that of a cast iron furnace of equal power. Since, then, the latter can be made to answer all requirements at a less cost, it would seem to be better adapted for general use.

But in any case good results cannot be obtained from cheap and inferior apparatus. The tendency to cheapen everything in the point where there is only an appearance of value, and only substance enough to enable the object to stand up until its sale is completed, will overpower and destroy the wrought iron furnace in its turn. It is now about to bring discredit upon steam apparatus, and it is extremely doubtful if there is a single case of heating by steam on a small scale which could not be better done by a good furnace at half the cost. For small dwellings and schools, where economy must be taken into account,

liberal expenditure for the best, but only the best, furnace work will be infinitely better than a cheap and half-complete steam apparatus, constructed at nearly twice the cost. Lest these ideas should seem to be retrograde, let it be borne in mind that it is not the best that is sought for, but the best for the least money, which is a very different thing from the cheapest. In other words, a superior article of an inferior class is to be preferred to a poor article of a higher class, and it generally costs much less.

There is another way in which the quality of the air is dependent upon the heating apparatus. It is the means whereby the relative humidity is kept up, or moisture added in proportion to the increased temperature of the air. All natural air contains among other constituents a portion of watery vapor. The amount is very variable, but increases rapidly from lower to higher temperatures. By agreement among chemists, the total amount which the atmosphere can hold at each degree of the thermometer is called saturation. At 32° Fahr., it is two grains, and at 70° it is 8 grains per cubic foot. The excess above saturation is always manifest in the forms of clouds, fog, dew, rain, or snow. The actual amount found at any time is compared with the amount required to saturate it at the same temperature, and is stated as so much per cent., and called the relative humidity. In the Northern States the average relative humidity is 70 per cent., in England 80 per cent. Now, if we take air at 30°, of 50 per cent. relative humidity, and heat it to 70° without adding moisture as Nature does, we shall have a warm air of only 12 per cent. humidity. It is sufficient to say that no observation of natural air has ever been made which showed so low a degree of humidity. As far as the writer knows, the lowest relative humidity is found in spring on the eastern coast of Massachusetts, during the prevalence of the so-called damp east winds. So far from being damp are they that they are the very driest known, showing sometimes as low as 30 per cent. They are, according to the writer's observation, always followed by epidemics of catarrhal troubles; are unspeakably disagreeable, and detested by everybody. North west winds in the early

spring, when the earth is partially covered with melting snow, often show the same character, and are mistaken for east winds by unobserving people. The cause of their dryness is to be found in the absorption from the atmosphere of its vapor by the exceedingly cold water of the Arctic current east of New England. It seems paradoxical that water should absorb moisture from the air, but it takes place precisely as frost is deposited on a cold window-pane. A melting block of ice placed in a dish, and balanced on a pair of scales in a warm atmosphere, will shortly weigh down the beam by aid of the weight of the moisture or dew precipitated upon it. In the same way the west wind, already comparatively dry, yields up its water to the masses of melting snow. The instinctive dread with which these winds are regarded is corroborative proof of the close connection of the low rate of humidity with many diseases of the breathing organs, without ascertained facts showing them to be the cause. But since the characteristic of spring air is its dryness, and during that time such disorders are prevalent, it is safe to conclude that dryness is the cause, or at least an accomplice.

Such are the effects of a dry atmosphere at low temperatures, when the air although saturated holds but little water. What may be the effects of the dry air at the high temperature of our houses, which is relatively even drier than the hated east wind, and which has five or six times the capacity for absorbing moisture from the lungs and skin which the colder natural air has? Perhaps the doctors can identify disorders, not febrile, but which could be explained by supposing the blood to have lost a portion of its water which in health is invariable in quantity. Would it be safe to hint that rheumatism and neuralgia might be some of these, and that there might be others, of a febrile nature with a specific cause, which owed their origin to the inability of the deranged blood to repair waste and fortify the system against attacks which healthy people in other climates are not subject to?

It was said before that the relative humidity was variable even in natural air. In fact, it varies from hour to hour,

but in pleasant climates it seldom falls below 65 per cent., and the more limited the range the more agreeable the climate. Increased ventilation means diminished humidity, since there are many unrecognized sources of moisture in every house, and if the air is frequently changed, of course these are less able to keep up the supply. In most well-ventilated furnace-heated houses the humidity will not rise above 30 per cent. in cold weather, while in buildings heated by steam or hot water, on the indirect system, the amount will generally be below 20 per cent., sometimes at 15.

It is important to avoid all schemes of ventilation which provide for the admission of unwarmed air through windows or wall-openings. It is next to impossible to so arrange the distribution as to avoid draughts, which will certainly lead to the permanent closing and neglect of all such openings. The more draughts there are, or the more rapid the movement of air in schoolrooms and halls, the higher should be the temperature and the relative humidity. All the sting is taken out of a draught if it is warm and

unable to chill the body by absorbing the insensible perspiration too rapidly, as it cannot do if near the point of saturation. But if the distribution is well managed it is safe to introduce air as low as 65°. Any plan of ventilation which involves a multiplicity and complication of details will be certain to fail, either from ignorance of its construction and purpose, or from neglect and indifference to results. Finally, the requisites of a successful scheme are—the reduction of the number of parts, control of the movement of air at one point by one operation, regulation of temperature without interfering with the quantity of air supply, accessibility to all parts so that they can be cleaned or repaired without trouble, all the unavoidable mechanical movements to be as simple and self-evident as they can be made, and suitable apparatus for the evaporation of water to be included. It is safest that the entire plan of the heating and ventilating should be decided upon and incorporated into the general plans of a building before the first step is taken towards its construction.

## THE PORTABLE ENGINE OF THE FUTURE.

From "The Engineer."

We have good reason to believe that the demand for portable engines to be used in Great Britain, which has been becoming smaller and smaller for some time past, will soon cease almost altogether. The only engines of the kind which will be built in a not distant future will be sold in foreign markets or purchased for home use solely by builders and contractors. This statement will hardly take any of the great agricultural engineering firms by surprise, however startling it may appear to others. But no alarm need be felt; an important branch of trade will not be cut off. The place of the portable engine will be filled by a kindred machine, in the production of which profits may be made and a large business done. In order that we may understand what this machine will be—what, in a word, is to take the place of the portable engine—we must consi-

der the nature of the circumstances which have led to the change. In Great Britain portable engines are bought—putting contractors on one side—by two distinct classes. One of these consists of men farming large tracts of land and possessing two or more homesteads, often some miles apart. These agriculturists use the portable engine almost exclusively for thrashing; and the engine and machine have to be moved as occasion requires from farm to farm. The removal will require, on an average, the services of six horses—four to draw the engine, and two to draw the thrashing machine. The horses are taken for this purpose at a time when every hour is of importance to the farmer who wishes to get his land ploughed, or his roots led home; and this the owner of the engine, machine, and horses regards as a very serious evil. The second class of British

purchasers consists of men who either hold no land, or very little. They invest some hundreds of pounds in the purchase of one or more sets of thrashing machinery, and they make a livelihood by hiring them out to farmers who do not grow corn enough to give employment for more than a few days in the year to a thrashing machine. The rule is that each hirer of the set shall send his horses for it to the place where it was last employed. If the tiller of hundreds of acres grumbles at the loss of the services of six horses for a day or two, how much more inconvenient must the loss of his teams prove to his poorer neighbor? The difficulty of the case is of course augmented when, as sometimes happens, the small farmer has not got six horses to send for the engine and thrashing machine. So long as there was no help for this state of affairs, the farmer had perforce to submit. But he has not been blind to the fact that certain owners of the machinery which he wanted did not use portable but traction engines; and for a very small extra hire—sometimes without any additional cost whatever—engine and machine came together to his stackyard, thrashed as much corn as he wanted, and went away without at all interrupting his field work. The result is that he who possesses a traction engine always has the pick of the market for his thrashing machinery; and it has already been discovered that it will not pay to purchase portable engines to be hired out, while a neat little income can be realized if the engine will propel itself and a thrashing machine from farm to farm. The holder of great tracts of tillage land finds precisely the same benefit result from the substitution of the traction for the portable engine, and it is thus day by day becoming more evident that those who wish to build agricultural engines for sale in this country must give them powers of self-propulsion.

Are we then to believe that the traction engine will take the place of the portable engine? The answer to this question will depend altogether on certain conditions; and bearing this in mind, we may say that it is not unlikely that a demand will exist for two classes of engines. The large landholder will probably prefer a portable engine fitted

with self-propelling gear, because such an engine will be lighter, simpler, and cheaper than traction engines. But those who purchase engines that they may hire them out will prefer traction engines whenever it is likely that they can get employment for them in hauling coal, corn, manure, &c., on the high roads, because in such cases the engines need hardly be idle at all throughout the year; whereas engines fitted only for thrashing are worked for but a couple of months or so at the most, and lie by for the rest of the time. It is quite impossible to say for which class of engines the greatest demand will spring up, but it is not difficult to define the conditions which will tend to limit the demand for traction engines proper. We may assume, for the moment, that the state of the law will exert no material influence one way or the other, and we must look therefore to the machine itself for the causes which will affect its popularity. Comparing the traction engine with the portable engine, it is obvious that the former is, for a given power, much heavier than the latter. This increase of weight is caused not only by the presence of the gearing required to drive the road wheels, but by the augmentation in strength which must be carried out right through. A traction engine ought to be stronger in all its parts than a portable engine. If it be not stronger, it soon knocks itself to pieces on the roads, as the traveling strains, as we may term them, to which it is exposed, are much more severe than those which the portable engine has to withstand. It would be easy to explain why this is so; but we fancy our readers will be content to accept as proved what they must very well know to be true. Now augmentation of weight in engines intended to travel over ordinary parish roads is very objectionable, because of the multitude of small bridges and culverts which are far too weak to carry heavy loads. We could cite instances wherein ploughing engines have had to make a round of six or seven miles to go from one farm to another not more than a mile off, in order to get to a bridge strong enough to carry them. It may be said that the bridges ought to be made strong enough. We shall pronounce no opinion on this point; but

whether they ought to be strengthened or not, it is at least certain that there are large districts of country in which at present the use of any engine weighing more than six tons is almost impossible, because of the weakness of certain parish road bridges spanning small streams. Another factor tending to limit the demand for traction engines is found in the cost of repairs, which it is not too much to say never comes to a sum less than twice as much as would suffice to keep a portable engine in excellent order, while it is often five or six times as great.

If, now, we compare the self-propelling engine with the traction and the portable engine, it will be seen that several points may be urged in its favor. In its simplest form the self-propelling engine is an ordinary portable, a little strengthened in a few places. On the crank shaft is fitted a chain pinion. The hind axle revolves in bearings at the back of the fire box, and is driven by a chain wheel keyed on it. The road wheels are caused to revolve by shifting pins in the usual way, which pins can be removed at either side when a sharp corner has to be turned. At the back of the fire-box is hung a kind of removable tray or foot-plate for the driver, which provides room for about 1 cwt. of coal, any additional quantity required being conveyed in bags on the thrashing machine. Water is carried in a tank under the barrel of the boiler. Engines of this type were built several years ago by Messrs. Barrett, Exall, and Andrews, of Reading, and possibly by other firms, and answered very well. At the time, however, no sufficient demand had sprung up for self-propelling engines, and but few were made. Of such engines, it may be urged that they can be much lighter than a traction engine. So much lighter, indeed, that any bridge which will carry a portable engine may be trusted to sustain one. They will also be cheaper as regards first cost and repairs than a traction engine. But on the other hand, it must not be forgotten that their use will be practically limited to the performance of the ordinary duties of a portable engine, and they will be unfit to draw heavy loads. The intending purchaser will no doubt bear these facts in mind, and decide which class of en-

gine will best suit his purpose; but agricultural engineers may feel certain that for both kinds of engine a large demand will spring up ere long. Out of the manufacture of which class of engine the greatest profit may be made we cannot pretend to say. But it would appear that before laying himself out for the production of either the one or the other, the engineer should study the nature of the district in which his customers live, and shape his plans accordingly.

It is not improbable that a good market might be found for a fourth type, namely, a very light traction engine, which would be competent to convey moderate loads at a speed a little greater than that of horses, say, four to four and a-half miles per hour. In order that such an engine may be kept as light as possible, it should have but one speed, and either carry steam of, say, 80 lbs. to 90 lbs. pressure, or else have the cylinder made a little larger than usual, in order that sufficient power may be available when a bit of steep hill has to be surmounted. It will be essential to the success of such an engine that it is carried, as regards the driving wheels, on springs. These need not be very flexible, but their use would permit the weight of the boiler, and most of the moving parts, to be kept down to those of the ordinary portable engine. With the demand no doubt engines of this type will spring up. In a word, the traction engine and its congeners is coming once more into prominence, and so much experience has been acquired in the practical use of steam on common roads within the last twenty years, that a very successful result may be anticipated. However, some men will make mistakes, and we shall not be surprised if certain very singular examples of the self-moving agricultural engine are found in the Agricultural Hall at Islington next December.

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THE FRENCH IRON TRADE.—The French iron trade is suffering, to some extent, from the uncertainties attending the French political situation. Prices have, however, been pretty well maintained at Paris, merchants' iron having made £7 4s. per ton. Pig is generally quoted at £2 12s. per ton in the Meurthe-et-Moselle.

## HISTORICAL SKETCH OF EXACT RECTILINEAR MOTION.

By G. BRUCE HALSTED, Fellow of Johns Hopkins University.

Written for VAN NOSTRAND'S MAGAZINE.

THERE has appeared in Macmillan's "Nature" series a little book with the queer title, "How to draw a straight line." Now, though one might not suspect it, this little book contains the elementary principles of a subject of highest scientific importance, which should be of especial interest in America, the land of practical applications. Its author is A. B. Kempe, the same who in 1875 presented a paper to the Royal Society, "On a general Method of producing exact Rectilinear Motion by Linkwork," which was reprinted in Van Nostrand's Magazine. This article does not seem to have attracted here the attention it deserves. The desire to awaken a little more interest in the book has moved me, as much as the intrinsic merits of the subject, to prepare a short historical sketch of a chapter of progress of which this little book is the last and most elementary outcome, a chapter which seems to furnish a very beautiful example of how the torch of science is passed from hand to hand, from land to land.

It is well known that the so-called Parallel Motion used in steam-engines was invented by James Watt, and in the specification of a patent granted in 1784 is described by him as "directing the piston rods . . . so as to move in perpendicular or other straight or right lines."

But the motion really produced is a sort of figure eight, no part of which is straight.

Now, it seems astonishing that in spite of the geometrical genius of the Greeks before the Christian era, and the eighteen centuries of time after it, no method had been discovered of describing a straight line, that simplest of all lines. Yet such was the case, and even when it assumed the highest practical importance in the steam engine, men were content with imperfect, approximate solutions. And well they might be, for as Prof. Sylvester has said, "the more he reflects on the problem to be solved, and the nature of the solution (essentially a process of

transformation operating on polar coordinates), the more he wonders that it was ever found out, and can see no reason why it should have been discovered for a hundred years to come." It was first obtained in 1864, eighty years after Watt's patent, by M. Peaucellier, then an officer of engineers in the French army.

He *first* solved in a manner, absolutely rigorous, the problem of converting circular into rectilinear motion. He announced it in general terms in the form of a question in the "Nouvelles Annales de Mathématiques," 1864.

Still he did not seem to appreciate the importance of what he had done, nor did it catch the attention of any one prepared to see its value; so it fell into oblivion for six years.

Yet there was at least one man particularly fitted to be vividly struck by it and see its importance.

This was the great Dr. Tchebicheff of Saint-Petersburg whose mathematical genius has been likened to that of Pascal. He had long occupied himself in attempting to prove the *impossibility* of the exact conversion of circular into rectilinear motion.

It would be interesting to investigate how it came about that in 1870, only six years after the first discovery, this wonderful conversion was rediscovered just in the right place, that is, in Saint-Petersburg, by one of Tchebicheff's students named Lipkine. His professor obtained for this fortunate youth a substantial reward from the Russian government, and this has since stirred up that most conservative body, the Institute of France, to confer its great mechanical prize, the "Prix Montyon," on Peaucellier, who gave in 1873 a detailed exposition of his discovery in the same journal which had published his first intimation nine years before. Meanwhile Lipkine had presented the theory and description of his apparatus to the Académie de Saint-Petersburg in 1871 and exhibited a model of it at the Vienna Exposition in 1873.

Some months after, Dr. Tchebicheff visited England, and there Prof. Sylvester happened to ask him about the progress of his proof of the impossibility of the exact conversion of circular into rectilinear motion.

Tchebicheff answered that, far from being impossible, it had actually been accomplished, first in France and subsequently by a student in his own class. He then left with Sylvester a drawing of the cell and mounting, consisting together of seven links. He had proved at least, he said, that it could not be accomplished with less than seven links.

Shortly after this memorable interview, Dr. Garcia the eminent musician and inventor of the laryngoscope, happened to visit Prof. Sylvester, and being shown the drawing, sent to the Professor next morning a model constructed with pieces of wood fastened together with nails as pivots, which, rough as it was, worked admirably, and drew forth the most lively expressions of admiration from some of the most distinguished members of the Philosophical Club of the Royal Society. Soon after, Prof. Sylvester exhibited the same model in the hall of the Athenæum Club to his brilliant friend, Sir Wm. Thomson, "who nursed it as if it had been his own child, and when a motion was made to relieve him of it, replied, 'No! I have not had nearly enough of it—it is the most beautiful thing I have ever seen in my life.'"

Prof. Sylvester's appreciation carried itself from admiration to accomplishment. He changed what seemed an isolated fact into a grand theory. He proved that every possible algebraic curve may be described by linkwork. This proposition as far as concerns curves of the first nine genera, and also for curves of the first six orders, or for any order where the degree of one of the variables in the representing equation is five or less, he demonstrated by a direct method. In using this method he found it necessary to prove that a general equation of the fifth degree can always be reduced to a trinomial form by *real* transformations, which, by Tschirnhausen's (the only method hitherto applied), as often as not is incapable of being done. This was a most remarkable discovery, which renders general

and always valid M. Hermite's celebrated memoir on equations of the fifth degree.

Prof. Sylvester was invited to deliver a lecture on this new theory at the Royal Institute, which he did, Friday, Jan. 23, 1874. There he stated that we are able to bring about any mathematical relation that might be desired between the distances of two of the poles of a linkage from a third, and are thus potentially in possession of a universal calculating machine. He exhibited and worked a cube-root extracting machine constructed on this principle, and claimed to have given the first really practical solution of the famous problem proposed by the ancients of the duplicated or multiplication of the cube. He stated that Dr. Tchebicheff had informed him that he had succeeded in proving the non-existence of a five-bar link-work capable of producing a perfect rectilinear motion, but there might be other seven-bar linkworks capable of solving the problem.

Fired by generous enthusiasm, and working on this hint, two young Englishmen, graduates of Cambridge, took up the subject. The one, Henry Hart of Woolwich, among other theorems of great interest, made the astonishing discovery that in spite of Tchebicheff's declaration of its demonstrated impossibility, he could construct a linkwork of only five bars which would exactly convert circular into rectilinear motion. This has since been proved beyond all doubt by such men as Cayley, Roberts, &c., to be absolutely the smallest possible number.

The other young man is A. B. Kempe, to whose article in VAN NOSTRAND'S MAGAZINE and subsequent little book we so much desire to call the attention of Americans. What he has done may best be learned from his own writings. Our earnest wish is that this science of linkages, which has traveled thus from France through Russia to England, growing constantly, may be taken up in this country, and that the American genius for application may add to the beauty of theory the beauty of practice. It seems to have illimitable possibilities in regard to all constructions in machinery.

We add a complete bibliography of

the subject, which here, without diagrams, it was impossible even adequately to adumbrate.

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## THE RESTORATION OF THE ANCIENT SYSTEM OF TANK IRRIGATION IN CEYLON.

By R. ABBAY.

From "Nature."

A WORK apparently pregnant with the largest and most beneficent results to the native population of Ceylon is in process of being carried out by the Colonial Government of that island. More than a thousand years ago a system of irrigation, the most complete and remarkable that the world has ever seen, was in successful operation in the Low Country, and the object which the Gov-

ernment has in view is to restore to something like its pristine fertility a large proportion of the immense tracts of land—many hundreds of thousands of acres in extent—that for want of water have fallen into a condition of the most utter sterility. Sir Emerson Tennant, writing twenty years ago on this subject, says, "The difficulties attendant on any attempt to bring back cultivation

by the repair of the tanks are too apparent to escape notice. The system to be restored was the growth of 1,000 years of freedom, which a brief interval of anarchy sufficed to destroy, and it would require the lapse of long periods to reproduce the population and recreate the wealth in cattle and manual labor essential to realise again the agricultural prosperity which prevailed under the Singhalese dynasties. But the experiment is worthy of the beneficent rule of the British Crown under whose auspices the ancient organization may be restored amongst the native Singhalese."

The origin of the system of irrigation spoken of dates as far back as the year 504 B.C., when, according to the Singhalese Chronicle, Mahawanso, the first tank was built in the neighborhood of his new capital, Anuradhapoora, by Panduwasa, the second of the Hindu Kings. This was succeeded about seventy years later by two others formed in the same neighborhood. In the year 459 A.D., the Kalawewe Tank, the largest of all, was completed. The retaining bund of this immense sheet of water is twelve miles long, and the circumference of the lake which it formed was no less than forty miles, the water being backed up for a distance of fifteen miles and conducted from the tank by means of a conduit sixty miles in length to the capital. Sir Emerson Tennant in describing these remarkable reservoirs, says, "Excepting the exaggerated dimensions of Lake Mæris in Central Egypt, which is not an artificial lake, and the mysterious basin of Al Aram in Arabia, no similar constructions formed by any race whether ancient or modern exceed in colossal magnitude the stupendous tanks of Ceylon." The same author estimates that at the time of its greatest prosperity the island contained a population of from fifteen to twenty millions, nearly all of whom must have derived their means of sustenance from irrigated lands. At the present moment, after all the care bestowed through three-quarters of a century by a paternal government, the population only amounts to 2,400,000, whilst even for this a large proportion of the food—6,000,000 bushels of rice annually among other things—has to be imported from India, and the population itself must be considered to have been

somewhat unnaturally increased during the last fifty years by the stimulus of European enterprise. The mass of the people too have changed their place of residence from the interior to the neighborhood of the sea-coast, where trading and fishing instead of rice-cultivation furnish them a livelihood. The vast areas which formerly under the magic influence of a sufficient supply of water and a hot sun, produced their two or three crops of rice in a year are now absolutely deserted, frequently not a single inhabitant surviving where once a thousand found ample means of subsistence. The city of Anuradhapoora, if its ruins afford us any means of estimating its magnitude, must have covered an immense area—no less than from thirty to forty square miles, and the population living on the spot and drawing its supplies of food from the immediate neighborhood must have been correspondingly immense. Now it is a mere village in the midst of vast heaps of ruins.

One of the most gigantic of these early irrigation works is supposed to have been originated by Maha Sen about the year 275 A.D., and, having been enlarged by Prakrama, Bahu I., who reigned in 1153, to have received from him the name of "The Sea of Prakrama." It consisted of a series of lakes formed by an embankment twenty-four miles in length and from forty to ninety feet high, by which the water of a large river and many considerable streams was hemmed in along the base of a range of hills and so forced into the valleys that a series of lagoons or lakes was formed extending for the above-mentioned distance, and frequently several miles in width. A canal five miles in length conducted the waters of "the sea" to the Minery Lake, another of the works of Maha Sen, to be mentioned presently, and a further canal from Minery led the waters to the neighborhood of Trincomalie, in all a distance of fifty-seven miles. When it is remembered how sudden and torrential the rains are in a country like Ceylon—the writer has known 18 inches of rainfall in forty-eight hours over a very large extent of country, and at one spot as much as 18.9 inches in twenty-four hours,—we cannot too much admire the vastness of such a work and the skill

which enabled the native engineers to use the natural features of the country in such a manner that, for a distance of twenty-four miles, a single embankment sufficed not only to hem in the water for purposes of irrigation but also to provide a water-way for the transport of produce and merchandise. Along the whole course of this embankment and canal and wherever its tributaries carried the life-giving water there would be without doubt a teeming population; for irrigable land in Ceylon is capable of supporting, according to official calculation, 1,000 persons to the square mile. In 1855 there was not a single inhabited village, although a few patches of land were occasionally cultivated by people from a distance. The contrast between the remote past and the present condition of this half of the island is a painful one to contemplate, but it is to be hoped that the Colonial Government will never stay its hand until all the useful works of ancient times have been restored and improved—but this will be a work of centuries.

Long before the Christian era the main ambition of the kings of Ceylon appears to have manifested itself in the formation of tanks, and many kings are mentioned in the Mahawanso who, "for the benefit of the country," and "out of compassion of living creatures," built a dozen or more of these splendid, but absolutely necessary, irrigation works. The Minery tank, some twenty miles in circumference, and irrigating an enormous area of fertile land now entirely barren, owed its origin, along with sixteen others, to Maha Sen, who reigned about the year 250 A.D. It is now merely a swamp, resorted to by enormous numbers of wild fowl. Up to the twelfth and thirteenth centuries Ceylon produced her own supplies of food, but in the fourteenth it appears that the island was obliged to import a portion of it from India. In 1301, it is related that there were 1,470,000 villages in Ceylon. In 1410, as many as 1,540,000, the term village implying hamlet, or even a single house where there are people resident. Of the vast majority of these, if they ever really existed, not a vestige is left except the ruined tanks, which show unmistakably where the foci of population formerly were. This was shortly after

the conquest of the island by the Malays, who are believed not to have actually destroyed the fabric of the embankments, but by their system of government to have disorganised the village communities to such an extent that the works connected with the tanks fell into disrepair through neglect, the land became imperfectly irrigated, and the population gradually died out. That this process was a perfectly natural one seems evident from the fact that the tanks do not show any traces of wilful damage, and also from the consideration of the almost innumerable evils resulting in death, of which a scarcity of water in a tropical country like Ceylon is productive. Indeed one of the most frightful diseases that have ever scourged the human race is believed to have been developed in these very localities chiefly through the want of proper food, caused by the absence of a system of irrigation. It is believed, too, and there is strong evidence, based on experience, for the belief that the disease entirely disappears wherever irrigation is restored. It will naturally be asked, "If the advantages of a plentiful supply of water are so enormous, why have not the tanks been restored before this, and what hinders their immediate restoration at the present time?" The reply is, that the creation of this magnificent system of irrigation was not the work of a decade, or even of a century, but of a thousand years of successful national development, and that therefore the restoration of it must be also a work of time.

The object of this paper is to draw attention to the fact that the experiment of restoration is at the present moment in process of being tried, and bids fair, after the lapse of half a century or so, to alter entirely the character of the island. The most remarkable success has already attended the efforts to afford irrigation facilities to the Singhalese on the East Coast. Where but a few years ago the natives were half-starved, and the land apparently in a hopeless condition, the re-introduction of irrigation through the assistance of the Government has transformed not only the people, but the country, as if by magic. Rice-fields, palms, and other fruit-trees abound, and the population is increasing at a rapid rate. Of this particular district the

present Governor of Ceylon (Sir William Gregory) reported some four years ago to the Legislative Council of the island in the following terms :—"In the month of April I visited the rice-growing regions of the Eastern Province, which are the creation of the irrigation works carried out by the Government. I never before saw such an unbroken sheet of grain. Save where some isolated trees, part of a recent forest broke the view, the eye wandered over some 20,000 acres of green paddy. I saw, wherever I went, a sleek, vigorous, well-fed, and thoroughly healthy population. Up to 1864 the lands under cultivation in this province were 54,000 acres, the chief impetus to the irrigation scheme having been given in 1857. In 1871 the lands in cultivation were 77,000 acres. The Crown lands to be additionally reclaimed under works already completed or in course of completion, amount to 15,900 acres, equal to the support of 23,850 persons." Again, speaking in the same report on the subject of the Great Tank already mentioned, he says: "I am most anxious to put the full strength of the department at work in restoring irrigation to Nuwara Kalawia. This magnificent district has the strongest claims upon us. It was once the granary of the island. It is now utterly neglected. It has a population of 60,000 persons and over 1,600 villages, which have each of them their tank. There are at least 1,700 of these tanks, and I am credibly informed not one of them has a sluice in order. I trust that a few years hence the population may present the same vigorous and thriving appearance as the population of the Eastern Province, and from the same causes—namely, good and plentiful food." Of this same district a gentlemen of very great experience told the writer that in traveling through it many years ago he came to a village where, of the thirty inhabitants, only one of them was able to carry water, all the others having been stricken down by hunger or disease. This destitution was caused by the failure of three successive rice-crops, and was not specially exceptional, but fairly representative of what takes place frequently in the district. If we compare the scenes of plenty and contentment as they exist in the Eastern Province at the present mo-

ment with what meets us in the Wanni, or in any of the northern districts, where tanks have not been extensively repaired, the contrast is most striking. We find an almost depopulated country, with here and there a wretched village peopled by a few miserable and more than half-starved inhabitants, who, in times of scarcity, which are not infrequent, are obliged to live on roots and wild herbs, who are periodically decimated by a frightful disease, yet who seem bound to the spot where they were born, and prefer to die there rather than move away to a more fertile and healthy district. It is, indeed, this disinclination which possesses the agricultural Singhalese to move more than a day's journey from his home that presents the greatest of all difficulties to the scheme for the restoration of the tanks. It is on this account that the process of restoration is always in advance of the supply of natives to take up the new land, unless the works happen to be in the immediate neighborhood of population. The only plan, therefore, that has proved really successful under present conditions is to restore the tanks in the vicinity of villages, and induce the population to creep slowly onwards step by step, cultivating the more fertile pieces of ground as it advances, until the depopulated districts shall have been partially reclaimed, when the completion of the work will be a matter of comparative ease. Two typical instances of this mode of procedure have been mentioned to me by an official high in the Government service, as showing the effect of a well-regulated expenditure of labor and money in restoring irrigation works. In the year 1854 Mr. Bailey, whose name will ever be associated with this scheme for benefiting the natives, spent less than £100 on a canal some miles to the north of Matalé, a country town a few miles north of Kandy. The village thus supplied with water had previously dwindled away until only three houses were left, the rice-fields were deserted, and the famine-stricken inhabitants declared that they would die where their fathers had lived and died rather than migrate to a part of the country that was unknown to them. Ten years after the improvement was made the spot had become a little oasis in the desert; nearly two hundred

acres of rice were under cultivation, yielding about thirty bushels per acre, and supporting a population of several hundreds.\* Almost in the same neighborhood a sum of between £200 and £300 was spent on an old canal fifteen miles in length by the same zealous Government official already mentioned. Many hundreds of acres were brought under cultivation, and in ten years' time, instead of a starved and fever-stricken population of 150 inhabitants, no less than 500 able-bodied men were on the list as liable to the road-tax. The changes in these, as in other instances, took place as if by magic, yet the means employed in effecting them were of the most limited and simple nature. The secret of the success lay in the fact that a famishing and disease-smitten population was within a few miles of the spot, and the remnants of ancient engineering skill were ready at hand to guide the laborers on to certain success. Since the above tentative experiments were made, very great changes for the better have taken place in the condition of the agricultural part of the native population. The carrying out of the scheme for the restoration of irrigation works is recognized as one of the chief duties of the Colonial Government, and there is little danger that, after the real success which has attended it so far, any future Government will allow it to be interrupted. The policy of the Colonial authorities may be summed up in the pregnant words of Sir Wm. Gregory's address to the Legislative Council in 1876: "I consider that at least 100 tanks should be supplied with sluices, and properly repaired each year; and I have asked the Secretary of State to furnish me with an additional number of well-trained officers, by whom these works will be carried on with vigor. There is no boon which the Government can confer on the villagers more legitimately than this. It is a reward for their own exertions, and I am confident that each year, as it becomes better understood, it will be more appreciated, and that it will be recognised everywhere that the Government have no other object in it than to increase the comfort and re-

sources of the people." It will appear, from what has been quoted, that the tanks are not repaired free of cost and then handed over gratuitously to the villagers, but the natives are required to give a certain amount of labor in restoring the tanks, and also to pay a small rent or tax on the land cultivated, so that, whilst the native cultivator is the chief gainer by the undertaking, the Government is no loser. If there could have been a doubt as to the wisdom of the Tank Restoration scheme, the experience of the last three years must have dispelled it and proved how absolutely necessary a system of irrigation is to the welfare of the natives. In the address above quoted, whilst speaking of the cholera and other diseases which had visited several of the provinces, the Governor says:—"It is remarkable that the inhabitants of the Eastern Province enjoyed perfect immunity from epidemics of all kinds. It is an interesting question, on which I do not give an opinion, whether this general immunity from disease in the Eastern Province is due to the abundant supply of food throughout the populous part of it, the result of irrigation works." At the same time he speaks of the restoration of two of the large tanks as complete. One of these will irrigate 23,000 acres, equal to supporting a population of 35,000 persons; the other will bring large tracts of magnificent land into cultivation, and dissipate the unhealthiness of the district which has hitherto prevented settlement.

To look back over the early history of the attempts under Sir Henry Ward to restore the above system of irrigation, is like reading the accounts of the commencement of a successful campaign. The difficulties encountered were sufficient to discourage even enthusiastic philanthropists, chief amongst them being the utter disorganisation of the village communities through the abolition of compulsory labor and the rooted dislike of the natives to migrate from one spot to another. For the recent part of the evil caused by this disorganisation the British Government was alone to blame, for in abolishing *Rajekaria* they abolished the right of compelling villagers to keep their tanks and water-courses in repair. By doing this they practically placed the distribution of the

\* Irrigated rice-lands in the low country will support a population at about the rate of 1,000 persons to the square mile.

most valuable property of which the natives were possessed in the hands of the strongest, and consequently the most unscrupulous inhabitants of each district. In a dry season, when there was barely sufficient water to irrigate the fields along the course of a canal, those who were nearest to the source of supply would probably get more than their share, whilst those who were furthest from it and had an equal claim on it might get none; but, generally, the strongest party would get the advantage, to the ruin of the weaker. Dams would be built at various points along the course of the stream by one party, and as quickly destroyed by another. Interminable feuds were the results, and appeals to the courts of law, which, not being guided by native customs, only made matters worse. The canal, too, which ought to have been kept in proper repair by the united efforts of all who benefited by it, was allowed to fall year by year into a more ruinous condition, after compulsory assistance had been abolished, the residents on the upper portion of it refusing to aid those on the lower to repair the breaches made by the annual floods. Consequently the work that was done was ill done, and only of a temporary character. Soon it became beyond the power of isolated communities to effect the necessary repairs; the lands fell out of cultivation, and the population, after a long struggle with their neighbors, either died out or sought a living elsewhere. The early legislation in 1856 was based on a revival of the native customs and a compulsory distribution of the necessary work among the different villages, a majority of two-thirds of the inhabitants being enabled to place the lands under the Irrigation Ordinance, and to compel the assistance of all who benefited by the supply of water. The scheme resulted in complete success. It met the great want of the natives, and the interminable disputes about boundaries and rights of water, which was as much property to the natives as the land itself, soon ceased. The Government claimed its own and sold large portions of it by auction at a very reasonable rate, the upset price being generally £1 per acre, the land continuing to be chargeable with a yearly tithe to the Government of from 3s. to

4s. per acre. In special cases the Government granted even easier terms in order to induce the natives to settle in particular localities. Newly-purchased land was allowed to be free from tithes for four years, and the purchase-money was spread over an equal period from the time of sale. The pecuniary result was most gratifying to the Government, and the benefit conferred on the natives inestimable.

A few words will be sufficient to describe the character of the cultivation which this system of irrigation is intended to promote. A crop of rice, or paddy, as the undressed grain is called, requires about ninety days to come to perfection, and during this time it must be supplied with about thirty inches in depth of water, or a little over 4,000 cubic yards to the acre. The first and second watering of the paddy takes place within a fortnight of the sowing of the seed, and the water is only allowed to remain on the land for a short time. The three subsequent waterings take place about the twentieth, the fortieth, and the sixtieth days after sowing, from eight to ten inches of water being used each time, and the water is allowed to remain on the land until it has evaporated. This system, though more or less modified according to the climate and the supply of water, is fairly representative of rice-cultivation in the lowlands of Ceylon. The official estimate of the produce is about thirty bushels per acre. It is probable that exactly the same system existed in the very earliest times, and that the Singhalese engineers were able to regulate the flow of water through the tank sluices just as they wished. It certainly seems unreasonable to suppose that the men who could design such a vast irrigation system with no better means of levelling than that of leading water by actual experiment from one point to another, should fail in minor matters such as sluice-gates. Yet the writer believes that nothing is known as to the manner in which the flow of water was regulated. It is true that in some of the sluices a square masonry well is found leading upwards from the sluice soon after it has entered the embankment from the tank, but there is nothing left to show how it was used. Captain Sim, R. E., some years ago suggested that it

was intended to break the force of the water rushing in flood-time towards the sluice, and reduce the velocity of the water in the sluice to that due to the pressure in the well only. I am however inclined to think that a frame of wood, somewhat in the shape of a box strongly braced together, was fitted into the well, so that it could rise and fall readily under the influence of the water in the tank, and that by placing weights on the top, the frame might be forced down so as to cut off either partially or wholly the water issuing through the sluice. Wherever rocky foundations could be found for a dam, or a ledge of rocks for a spill-water, the native engineers, as if distrusting artificial constructions, would be sure to utilise them. In some cases, where it was possible to include masses of rock in the embankment, the sluices themselves would be cut out of the solid gneiss and the work thereby rendered as indestructible as the rock itself.

It will no doubt be somewhat surprising to persons who are only acquainted with the system of rotation of crops in vogue in Europe, that these rice-lands can be made to produce year by year for hundreds of years consecutively, one or two crops of grain annually without the land becoming exhausted or requiring to be continually renovated by manure. The explanation, however, seems to be that sufficient vegetable matter is carried down from the hills, partly in solution and partly in suspension, in water to supply all the waste produced by the continuous cropping. Those who have visited the richest alluvial valleys of California and Australia will no doubt have been struck by the fact that the most fertile soil is always found where the alluvium has been deposited in extremely fine particles, and in water practically at rest, conditions which obtain in the paddy fields of Ceylon, and must have obtained formerly on the Hunter River in New South Wales, and in the valleys opening on the Bay of San Francisco.

I cannot better conclude this paper than with an extract from a minute by Sir Henry Ward, after a tour of inspection in 1859:

"The village of Samantorre is a very

fine one, and stands on the borders of the richest plain in Ceylon, containing, as it does, nearly 15,000 acres of paddy. Mr. Birch and Mr. Cumming informed me that the scene of joy and excitement exhibited by the whole population when the water first came down from the Ericanmam, in July, 1858, and saved a magnificent crop from destruction by drought, was one of the most striking things ever witnessed. Hundreds of people had collected at Samantorre as soon as they knew that the sluices were to be opened; and when the water was actually seen advancing down the bed of the dried-up river, the shouts, the firing of guns, the screams of the women, the darting off of messengers bearing the news in every direction, made a deep impression on all who saw it. They felt that a great work had been done, a great benefit conferred. But I feel also that under British rule this benefit ought to have been conferred thirty years ago upon a people so capable of appreciating it.

Indeed, knowing what I now know of the history of the Eastern Province, I hold that what the Government is doing in 1859 is simply the payment of a debt incurred by our rash interference with a people of whose habits and wants we knew nothing. This error is now in part repaired. 44,000 acres of land are already under paddy cultivation, and I see reason to believe that the amount will be not less than 60,000 acres in 1861, when the irrigation works have obtained their full development. But this will require constant attention on the part of the Government and of its local representative. The maintenance of the *system* must never be lost sight of, and should unforeseen demands for assistance arise they must be met liberally and promptly." The words of so successful a governor have not been forgotten. The present governor, Sir William Gregory, has devoted all his energies to the carrying out of what was so well begun. The survey and engineering staff of the colony has been considerably increased, and the restoration of nearly the whole of the ancient irrigation works, besides the creation of new ones, may now be considered to be only a question of time.

## THE SOURCE OF THE POWER OF THE TIDE MILL.

From "Engineering."

THE source of the power of the tide mill or the principles concerned in its action would appear to be regarded as a somewhat involved subject—at least it is not generally treated of in the text-books. Mayer's view, as is well known (as given in Professor Tyndall's book "Heat a Mode of Motion," page 433) is that the power of tidal machinery is derived at the expense of the earth's rotation. This is shown by the following passage: "Supposing then that we turn a mill by the action of the tide, and produce heat by the friction of the millstones; that heat has an origin totally different from the heat produced by another pair of millstones which are turned by a mountain stream. The former is produced at the expense of the earth's rotation, the latter at the expense of the sun's heat which lifted the mill-stream to its source."\*

No explanation of the *mode* of retardation of the earth's rotation by the action of tidal machinery is given in Professor Tyndall's book, or apparently in Mayer's writings—though the mode of retardation of the earth's rotation by the *friction* of the tidal wave is very clearly explained. As therefore we think the subject has some practical interest, and fully admits of elementary exposition, we propose to say a few words on the subject in this article, having previously considered the matter carefully.

The phenomenon of the tide consists, as is well known, in an elevated mass or protuberance of water, situated (approximately) in the line joining the earth and moon, this protuberance of water not being carried round by the rotation of the earth; so that by this rotation, objects are carried through this elevated mass of water or tidal wave, dipping gradually below the wave at one boundary and emerging gradually from the wave at the other boundary, giving rise to what is called the rise and fall of the tide. It is well to keep distinctly in view that (neglecting the relatively slow motion of the moon and only taking into

account the phenomenon of the ordinary diurnal tides) the tidal phenomena are not due to the rotation of the tidal wave about the earth, but to the rotation of the earth beneath the tidal wave, which itself is stationary. Thus the rise of the tide on a beach is not due to the movement of the tidal water up the beach, but to the movement of the beach underneath the tidal water. It is important to keep this in view for the proper realisation of the facts.

Let us suppose a reservoir carried round by the earth's rotation beneath the tidal wave, and let the reservoir freely fill and empty itself as it is carried along; then evidently there will be no work done in retarding the earth's rotation, and no work can be got by means of the reservoir. If, however, during the passage of the reservoir through the tidal wave, we impound a portion of the water and let the reservoir (by its rotation with the earth) carry away that portion of water in a direction from the tidal wave (*i.e.*, from the line joining the earth and moon), then this portion of water must be carried away in opposition to the pull of the moon which tends to retain it in the tidal wave; and since this carrying away of the water is done by the earth's rotation (carrying the reservoir with it) it follows that the earth's rotation is thereby retarded; just in the same way as it would be if we imagine that the entire tidal wave had been impounded and carried round with the earth, away from the line joining the earth and moon, which it tended to approach under the influence of the moon's attraction. What applies to the entire wave or mass of water applies to any portion of it, only the above extreme case may serve to put the fact of the retardation of the earth's rotation in a striking light.

If the water thus impounded be allowed to flow out of the reservoir and descend through a mill, then the power thus derived from the water is the exact equivalent of that abstracted from the earth's rotation. If, on the other hand, the water be retained in the reservoir so

\* Mr. Robert Mallet questions this view (*Phil. Mag.*, July, 1874).

as to come round (by the earth's rotation) to the tide wave on the opposite side of the earth, then (conversely) in the approach of the water in the reservoir to the line joining the earth and moon towards which it tends, work will be done by the moon in pulling this portion of water round, so that the earth's rotation will be accelerated by an amount precisely equal to the retardation in the previous case, and, therefore, on the whole, no retardation of the earth's rotation will ensue. At the same time no work is got out of the impounded water; so that, therefore, it becomes clear that in order to derive work from the water, the earth's rotation must be retarded, by an amount equivalent to the work derived.

To look at the same fact from a somewhat different point of view, we may suppose that instead of impounding water, work is derived by raising a floating body by the tide. Then if the rise and fall of the floating body be not artificially resisted, it behaves exactly as the equal weight of water displaced by it would do, and the earth's rotation is not affected in any way, and at the same time no work is derived. But if the rise of the buoyant body be artificially prevented, then the earth in the act of its rotation has to plunge this body below the stationary crest of water raised by the moon's attraction, and in performing this act, the earth has its rotation checked by an amount equal to the work done in plunging the floating body below the surface of the water. The *mode* of retardation of the earth's rotation will, we think, be very clear and obvious in this example.

If after the buoyant body has reached (by the earth's rotation) the highest crest of the tidal wave, and is there totally immersed, the body be then allowed to rise, then in this act the exact energy which was abstracted from the earth's rotation can be utilized for performing work. If then the floating body be allowed to sink freely again with the tide, no further retardation of the earth's rotation will ensue. But if the floating body be artificially confined at its highest level, or prevented from falling with the tide, then the rotating earth will do further work, for in the act of rotating it has to lift this body out of the water;

or in other words, the rotating earth in transferring the body (which is not allowed to fall) from a portion of the tide wave where the water is high, to a portion where the water is low, has in that act to lift the body out of the water, for the body is no longer immersed at the part of the wave where the water is low. In this act of lifting the body, the rotation of the earth is retarded by an amount equivalent to the work done in lifting.

If then, after the suspended body has been carried round by the earth's rotation to the boundary of the tidal wave (when the water is at its lowest), the body be allowed to fall, then work may again be derived from the body which exactly represents that abstracted from the earth's rotation in lifting the body out of the water.

The level of the water, it may be observed, is abnormally altered by the action of the moon. If it were not for this action of the moon, the surface of the water would always remain at the same level about objects on the rotating earth, and no immersion and emersion of these objects would take place by the earth's rotation: but on account of the abnormal elevation of the water opposite the moon, alternate immersion and emersion of objects necessarily takes place by the rotation of the earth beneath this elevation of water, and thus this rotation may be readily made to perform work.

Thus we observe that every operation of the tide mill takes energy from the rotating earth, and the inevitable conclusion follows that such operations, if continued long enough, would bring the earth to rest.\* The store of energy in the rotating earth is, however, so vast as to be practically inexhaustible by such operations in any time that we take account of. The rotative velocity of the earth's surface is such as to carry objects fixed on its surface, from the

\* In regard to the retardation of the earth's rotation through friction of the tidal wave (a cause quite different from that we have been considering), it may perhaps be worth noticing that the continual scour produced by the rotation of the earth beneath the tidal wave, may possibly be abrading the equatorial regions of the earth and transferring the abraded material towards the still water at the poles. The tidal wave has been aptly compared to a brake, and is in fact a brake formed of two halves of water inside which the earth rotates (the grip being applied by gravity). Few brakes can operate without a sensible abrading action, and the abrading power of water is well known.

lowest to the highest part of the tidal wave (a distance of one-fourth the earth's circumference at the equator) in six hours, so that a lift can be obtained from the rotating earth (through the mechanism of tidal machinery) at every such interval. It would appear that this vast

source of power were deserving of more attention than appears to be accorded to it, or that the problem of using the rotating globe as a driving power through the mechanism of the tide might be worthy of the attention of practical engineers.

## PRELIMINARY NOTE ON THE USE OF THE PIEZOMETER IN DEEP-SEA SOUNDING.

By J. Y. BUCHANAN, Chemist to the Challenger Expedition.

Proceedings of the Royal Society.

IN order to determine the depth of the sea independently of the length of sounding-line used, piezometers filled with distilled water were frequently attached to the line along with the deep-sea thermometers. The combined effects of change of temperature and change of pressure were registered by a steel index of ordinary form. The temperature of the bottom-water being given by the deep-sea thermometer, the effect of temperature on the apparent volume of water in the piezometer could easily be calculated; and from the residual effect, the pressure, and therefore the height, of the column of water to which the instrument had been subjected could be deduced.

The piezometer did not differ materially from the ordinary ones used for the determination of the compressibility of liquids. A minute description of the fittings necessary for their safe use on the sounding-line cannot be given without reference to a drawing or model, and must therefore be postponed.

It is manifest that if the apparent compressibility of water is accurately known, we shall be in a position to determine, by means of our instrument and a deep-sea thermometer, the depth to which it has been sunk, independently of the lengths of sounding-line used; for the indications of the instrument depend solely on the temperature of the water at the depth in question, and on its vertical distance from the surface.

The determination of the effect of change of temperature on such an instrument does not demand explanation. It

is, however, otherwise with the effects of pressure. In submitting an instrument of the kind to high pressures in a hydraulic machine, we encounter difficulty in accurately determining the pressure to which it is exposed, and also, although in a minor degree, in making our observations at the low temperature usually obtaining in deep ocean waters. I have therefore taken, as basis for the determination of the apparent compressibility of water, the results obtained when the instrument has been sent down on the sounding-line, either to the bottom or to intermediate depths, in positions where there has been no apparent disturbance from currents, and where the amounts of compression produced have been proportional to the depths recorded by the sounding-lines. Where currents are absent, and their presence is at once detected by the behaviour of the sounding-line, the depth, as determined according to the method of sounding adopted on board the "Challenger," gives an excellent measure of the pressure exercised on the instruments. As the variations in the temperature, the salinity, and the compressibility of seawater with the depth have been thoroughly investigated for the soundings in question, the weight of a column of seawater in any of these localities can be calculated with great accuracy.

The observations which have been taken as a basis for determinations of depth were made in the latter part of the year 1875 in the South-Pacific Ocean. They were twenty in number, and were made at depths varying from 500 to

2,300 fathoms, and at temperatures varying from  $1^{\circ}.4$  to  $4^{\circ}.03$  C. The mean compressibility of water determined from these observations was 0.0008986 per 100 fathoms of sea-water, the extreme values being 0.000915 and 0.000882. Observations made at greater depths in the North Pacific gave as a mean of six observations at depths varying from 2,740 to 3,125 fathoms the value 0.000878, indicating a slight diminution in the coefficient of compression at very high pressures.

The effect of pressure being thus known, we are in a position, by comparing the indications of the instrument with those of a trustworthy deep-sea thermometer, to determine the absolute depth to which it has been sunk beneath the surface; and assuming the depth as indicated by the sounding-line to be correct, we should be able to determine the temperature at the depth in question from the indications of our instrument, and without the use of a thermometer. For the latter purpose, however, the instrument, as above described, is useless, because the dilatibility of water at the low temperatures, obtaining in deep water, is so small as to be negligible compared with its elasticity.

The application, however, of the principle above indicated would manifestly present some very great advantages in the determination of deep-sea temperatures.

In the open ocean, where, as a rule, the temperature diminishes constantly as the depth increases, the Millar-Casella thermometer gives sufficiently accurate results. In the case of enclosed seas, or in the neighborhood of ice, however, this is not always the case. In the Mediterranean, the Red Sea, and many of the seas of the Eastern archipelago, besides, possibly, large tracts both of the Atlantic and Pacific Oceans, the temperature decreases regularly down to a certain depth, which is different for different seas; and at all greater depths the Millar-Casella thermometer gives identical readings, indicating that the water is either at the same temperature or some higher one. In the neighborhood of ice, layers of water are frequently met with at various depths whose temperature, being higher than that of the surface, is indicated by the maximum index of the

Millar-Casella thermometer. Besides these layers there may be, and there probably are, others whose temperature is higher than that of the water immediately above them without reaching that of the surface, and their temperature would remain unrecorded. It would therefore be of great advantage if the piezometer could be adapted for the determination of temperatures at known depths. An efficient instrument for this purpose has been obtained by filling the bulb of the piezometer with mercury instead of water. The portion of the stem in which the index moves is filled with water, and, as in the other, the open end dips into a cup of mercury. We have thus an instrument filled with a very large quantity of mercury and a very small quantity of water; and after immersion the position of the index shows the apparent volume assumed by this mixture under the combined influence of temperature and pressure. As far as the effects of temperature are concerned, the amount of water in the instrument is almost wholly negligible; but when the effect of pressure is considered, the apparent compressibility of mercury is so small, being little more than one-fiftieth of that of water, that the pressure of even so small a quantity of water as can be contained in the graduated tube increases very materially the amount of contraction produced by pressure. The instrument, which has been in use since the beginning of November last year, contains 256.61 grammes of mercury in the bulb and stem immediately above it; the volume of the part of the stem filled with water is 0.1935 c. c. The apparent contraction of this mass of mercury and water is 0.000581 cubic centimeters per 100 fathoms, and 0.0025 c. c. per degree respectively. A fall therefore of one degree in temperature produces the same effect as an increase of pressure equal to 430 fathoms of sea-water. Hence (and this forms the important peculiarity of the instrument) as long as the temperature of the sea does not increase with the depth at a greater rate than  $1^{\circ}$  C. per 430 fathoms, the instrument will record the temperature correctly. The ratio subsisting between the amount of temperature and the column of water, which produce the same effect on the apparent volume, is a

constant for every instrument; in our one it is  $\frac{1}{430}$ . By altering only very slightly the amount of water, the sensibility to pressure is greatly increased or diminished, while that to temperature remains practically unchanged. As the instrument was intended principally for bottom-waters, the above ratio ( $\frac{1}{430}$ ) was considered sufficient, and it has proved practically useful. It must be remembered that the greater the value of this ratio is made, the greater is the error introduced into the determination of the temperature by any inaccuracy in the measurement of the depth.

By attaching a combination of one, or better of two, of each of these instruments close to the weight at the end of the sounding-line, the depth of the sea and the temperature of the water at the bottom at any locality can be accurately determined, provided that sufficient evidence is afforded, either by the presence of a sample of bottom in the sounding-tube, or by the rate at which the line runs out, that the instruments have been at the bottom; otherwise the depth which they have attained and the temperature at that depth will be correctly given. For this purpose it is necessary first to let the line run out until, from observations on its velocity, it is evident that the weight has reached the bottom; the length of line which has so run out will give the depth approximately, but more or less in excess of the truth according to circumstances. Allowing for the contraction which would be produced by this depth in the case of the mercury piezometer, a first approximation to the temperature of the bottom-water is at once obtained; and it is sufficiently accurate for the purpose of correctly determining the contraction produced on the water piezometer by the change of temperature; and consequently for deducing the depth to which the instrument has been sunk. By now applying the more correct depth to the reading of the mercury instrument we obtain the correct temperature, and if necessary the approximation might be carried still closer.

As an example of the use of the combined instruments, the observations made on the 29th February, 1876, may be taken. The position of the sounding was lat.  $36^{\circ} 9' S.$ , long.  $48^{\circ} 22' W.$ , and

the depth by line was 2,800 fathoms. The sea was quite calm, but there was a strong current setting to the south-east, rendering it probable that the depth, as determined by line, was considerably in excess of the true depth. The mercury instrument registered 166.2 millims. In order to clear this reading for a depth of 2,800 fathoms, we have to subtract 16 millims., and we obtain 150.2 millims. as the corrected reading, from which we determine the temperature to be  $+0.2^{\circ} C.$  The reading of the water instrument was 283.8 millims. Assuming the temperature to have been  $0.2^{\circ} C.$ , this would indicate that the water had suffered an apparent contraction, owing to pressure alone, of 0.1923 c. c., which would be produced by a column of 2,480 fathoms of sea-water. Assuming now 2,480 fathoms to be the true depth, we find the corrected reading of the mercury instrument to be 152.1 millims., which indicates a temperature of  $-0.5^{\circ} C.$  The Millar-Casella thermometers gave the temperature as  $-0.4^{\circ}$ . Assuming this as the correct bottom temperature, and reducing the reading of the water instrument accordingly, we find the contraction produced by pressure to be 0.1924 c. c., which agrees sensibly with that found on the assumption of the higher bottom-temperature of  $+0.2^{\circ} C.$

It will thus be seen that the two instruments fulfil the conditions required of them; namely, that the one which is to indicate the temperature of the water shall be independent of great accuracy in the determination of the depth, and the one which is to indicate the depth shall be equally independent of accurate determination of the temperature; whilst by combining the results obtained by the two, an accurate determination is obtained both of the depth and of the temperature of the water at that depth.

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It may not be generally known that Prof. J. C. Poggendorff died in Berlin on the 24th of January last, at 81 years of age. In 1821 he wrote his treatise "On the Magnetism of the Voltaic Pile." In 1824 he was appointed editor of the *Annals*, a position which he retained until his death. He filled a chair in the University of Berlin since 1834, and was a member of the Berlin Academy since 1838.

## PHOSPHORUS AND IRON.

From "The Engineer."

THE Bessemer process has gone far to ruin the iron trade of England. While a good steel rail can be had for about £6 10s. per ton no one will buy iron rails, costing £6 and lasting one-third of the time. It is not impossible that steel boiler plates, and even ship plates, may yet be produced at a cost little exceeding that of iron, while they will be comparatively free from the uncertainty of quality which now militates against the extended substitution of steel for iron. We could, indeed, hardly be charged with rashness if we said that in a few years steel might so far have taken the place of iron, as a constructive material, that the latter would be made only on a small scale, and of the best quality for a few special purposes. It is well, however, to bear in mind that the position which the steel manufacture has assumed is due as much to the low price at which the metal can be produced as to the qualities of the finished article. It is not to be denied that there are very bad steel rails made and sold, and it is well known that much so-called steel is really iron produced by the Bessemer or Siemens-Martin process. That is to say, it will not harden, in the proper sense of the word, when heated and dipped in cold water, and its tensile strength and elongation under strain are more nearly those proper to good wrought iron than comports well with the popular idea of the characteristics of steel. The process, in a word, gives the product a name. Be this as it may, the growing popularity of steel, or so-called steel, is so rapidly destroying the iron trade, especially in rail-making districts, that it is beginning to be accepted as proved that a shire or a county which does not possess ores suitable for the production of Bessemer pig cannot hope to carry on a successful trade in rails, at all events; while it can hardly be found worth while to manufacture iron plates or bars alone in their absence, save in isolated works. Unfortunately for the Cleveland district, this is precisely the plight in which it stands at present. Possessed of enormous quantities of ore, while coal can

be had in abundance at low prices, Middlesbrough and the surrounding country are reduced to sore straits because they cannot make steel rails. The defect in Cleveland pig is very easily stated. It contains, besides other impurities, far too much phosphorus. Rails or bars made from it are consequently cold short to a dangerous degree; and it has become with the Cleveland ironmasters almost a question of life and death to clear their iron of the element which poisons it. It is no wonder, therefore, that energetic efforts are being made to discover some method by which the phosphorus may be eliminated. A great deal of money has been spent in this direction with little success. The last laborer in the field is Mr. I. Lowthian Bell, and he availed himself of the recent meeting of the Iron and Steel Institution at Newcastle to place his theories and proposals before the world. We have already published the discussion which followed on the reading of his paper, and that of one by Mr. Siemens. It is matter for regret that two gentlemen, so able, should have confined their attention during the discussion to matters which did not throw much more light on the subject they had in hand. We have already given an abstract of Mr. Siemens' paper, and we propose here to consider Mr. Lowthian Bell's communication. This last we have not published, because, in the first place, it is very long; and, in the second place, it is somewhat difficult to follow its author's line of reasoning. To abstract it would be impossible; but we can explain here very briefly how Mr. I. L. Bell proposes to free Cleveland iron of its phosphorus; and that, after all, is the most important question.

Last March, Mr. Lowthian Bell read a paper in London before the Iron and Steel Institute, in which he showed that carbon and silicon were expelled from iron at moderately high as well as at excessive temperatures, oxygen being the eliminating agent. The paper with which we are now dealing is a sequel to that read in London, and in it Mr. Lowthian Bell states that phosphorus does

not behave in quite the same way as carbon and silicon, experience acquired with the Bessemer converter proving that oxygen in its free state, or in oxide of iron, was entirely unable to remove phosphorus at exalted temperatures; that is to say, at these heats phosphorus and oxygen cannot unite, and the former element remains combined with the iron. To put this proposition into somewhat more popular language, although carbon and silicon can be burned out of iron at almost any heat within a wide range of temperature, phosphorus cannot. It remains to be seen if it can be burned out at any temperature. Mr Lowthian Bell states that it can. "When," he says, "*melted pig iron was exposed to the action of fluid oxide of iron at lower temperatures phosphorus was rapidly removed.*" We have put this passage in italics because it contains the essence of Mr. Lowthian Bell's discovery. The lower temperature is one somewhat less than that at which iron is puddled, very much less than that in a Bessemer converter while a charge is being blown. If Mr. Lowthian Bell is right, then his discovery ought, if it can be applied in practice, to revolutionise the trade of Cleveland. For that district he will have done more than Mr. Bessemer did for the world. It remains then to be seen, whether his deductions are sound, and whether the process can readily be applied under ordinary manufacturing conditions.

As regards the first point, we have no reason to question the accuracy of Mr. Lowthian Bell's views. He seems to have carried out his experiments very carefully. He first ascertained, for example, that at moderate heats he could get rid of phosphorus, and then he found out that at high temperatures the metal would take up the phosphorus again. In one instance a specimen of Cleveland iron had been so well freed from its phosphorus that only .055 per cent. of this substance remained. A portion of this purified metal was subsequently exposed to a strong heat, about equal to that of a puddling furnace, in contact with the cinder used in its purification. At the end of sixty-five minutes the phosphorus had risen to .153 per cent., and in three hours the iron contained .365 per cent. of this element. Results

like these are conclusive. The moment Mr. Bell had thus clearly opened his subject and laid down his propositions, he went out of his way to describe the results obtained with iron and steel rails made by different processes, and we have, in consequence, a great mass of figures and facts, which, however interesting, are really in a great measure beside the question, and break the thread of his discourse in a very disastrous fashion. It was hardly necessary, we think, to explain and prove at great length to the members of the Iron and Steel Institute that phosphorus was an extremely objectionable ingredient in a rail or a bar; Cleveland requires no evidence on this subject. Thanks to this digression, it is not until nearly at the end of the paper that we have any explanation of the way in which it is proposed to apply Mr. Lowthian Bell's discovery in practice. There we learn that he is engaged at present, at the request of the North Eastern Railway directors, in erecting proper apparatus for carrying on the necessary experiments on a practical scale. Upon an elevated platform a small cupola will be placed, in which the cinder or other form of oxide will be melted. From this the fused material will be run into a vessel revolving on its centre, into which the liquid iron direct from the blast furnace will also be introduced. It is expected that in this way a sufficient blending of the two fluids will take place to effect the object had in view. One of Messrs. Godfrey and Howson's puddling furnaces will be used for the revolving vessel. Its construction will enable the interior to be heated expeditiously when required, and thus avoid a cold surface cooling the materials before the necessary change is effected, while the power of inclining the vessel at an angle will permit the process to be continued to a point which must be determined by the extent to which it is wished to remove the carbon.

The information contained in the foregoing passages is meagre enough. It is clear, however, that the process consists in washing the melted iron in a cinder bath, which will extract the phosphorus. The cinder will, we presume, be subsequently tapped off, and the iron puddled in the revolving furnace. On this point we are not quite clear, however; that is

to say, we are not certain whether the iron, when washed, will be withdrawn from the rotator and puddled in the ordinary way, or whether the process of washing and puddling will both be conducted in a single vessel. Possibly this is a detail to be settled subsequently. The essence of the process consists, as we have said, in the use of melted oxide of iron as a detergent fluid. Mr. Lowthian Bell, very properly, was careful to point out that it had long been well known that a cinder bath will remove phosphorus. He is, however, apparently among the first, if not the first, to prove that the washing process can only be carried on at a moderate temperature; that is to say, just at or about the point of fusion of pig iron. Now, it is difficult to see how the carbon in the pig can be brought into contact with the oxygen in the bath without being burned out, but as it goes away the fusing temperature of the iron will rise, until a point is reached at which the phosphorus could be taken up again, while lacking this heat the iron would solidify in the hearth. This may prove a source of trouble, unless all the phosphorus can be expelled before the carbon is seriously attacked by the oxygen. It is fair to add that Mr. Lowthian Bell speaks very modestly indeed concerning the whole matter. "My plea," he said, "for occupying the attention of the members of the institute is the pains I have taken to discover the natural laws which govern the affinity

between the metalloids, referred to in the title of this paper, and iron. The effect of these inquiries has been to prove that by substituting moderate for the more elevated temperatures in use in our forges, phosphorus has been made to change places with the carbon in the order in which these two bodies leave the iron. Whether this fact will have any value beyond that which accompanies any contribution, however slight, to our knowledge on these subjects, remains to be proved. Its practical, or, in other words, its commercial importance, must depend upon the expense of removing the impurities from those cheap varieties of pig iron in which they occur." As bearing on the last few lines in the foregoing passage, we may extend the hypothesis of Mr. Stead, who took part in the discussion, and suggest that perhaps the cheapest way of applying the principle would consist in working a double-puddling furnace, very heavily fettled, at a low temperature for seven or eight minutes after the iron was all melted, and then running off nearly the whole of the cinder, and completing the process of puddling almost on a dry bottom. Much the same thing is done now, but the cinder is not present in sufficient quantity, the temperature is allowed to get too high in the earlier stages of the process, and the cinder is run off too late. The result is that much of the phosphorus taken out of the iron at first is restored to it subsequently.

## OTTO'S NEW GAS ENGINE.

Translated from "Le Gaz."

THIS new gas motor bears no resemblance to the other and older engine which bears the name of this inventor.

It consists simply of a piston raised by the explosion of a mixture of gases below it, and which is aided in its descent by atmospheric pressure, there being a vacuum below.

It is silent in its action, working horizontally much after the manner of the Lenoir engine, but upon another plan of action which we will proceed to describe. Like the vertical engine its economy of

working is well established, a cubic meter of gas, it is said, supplying the work of a horse-power per hour. It seems certain from observation that in the matter of regularity of action it leaves nothing to be desired.

The construction is simple. It consists of a working cylinder closed at one end, and within which moves a piston which is attached by a connecting rod to the crank shaft. Upon the shaft are the fly-wheel and working pulley.

The piston does not descend to the

bottom of the cylinder; the extra length of cylinder being equal to about half the stroke.

Suppose the engine working and the piston at the bottom of the stroke; the lower space is then filled with the gaseous products of the combustion as will be presently explained; the movement of the piston continues by reason of the momentum of the fly-wheel tending to suck in air until it has made half of a stroke. At this time the explosive mixture is introduced.

We have then in the cylinder three distinct sections sensibly equal, composed as follows: the first, next to the piston is a mixture of air and products of combustion; the second is pure air; and the third, at the bottom of the cylinder, is an explosive mixture of air and gas.

The movement of the engine continuing, the piston returns, compressing these three gaseous layers in such manner that when it has completed the stroke, the total volume has been reduced to one-third its original bulk, and consequently the gases are under a pressure of three atmospheres. At this moment the bottom layer, the explosive mixture, is exposed to a gas flame. The explosion is more or less rapid according to the mixture. The heat of the explosion causes great tension of the gases acting upon the piston during its third stroke, and during this stroke only is there any work imparted to the moving parts.

The piston having completed its upward stroke returns, driving before it the products of combustion, which escape by a valve till the piston has completed its fourth stroke and is in the position in which we began the analysis of its action.

Thus, after the work afforded by the combustion of the gases has been expended on the piston during one of the strokes, the piston makes three consecutive strokes without further impulse, and has besides to condense the gaseous mixtures to a tension of three atmospheres.

This action requires the function of a heavy fly-wheel, which further augments the importance of the passive resistances which are already very great, inasmuch as the piston is urged during a fourth only of its course by the moving agency of the machine.

In order to explain the better efficiency of this engine compared with the Lenoir engine, it is necessary to analyze the action of the latter.

The Lenoir engine receives the explosive mixture in the body of the pump. The explosion produces a very high temperature, and the escape of heat through the enveloping surfaces is very rapid. The piston moves but a short distance before a sensible loss of heat has occurred, and this of course implies a corresponding loss of tension of the gas. Furthermore, the heating of the pumps requires a cooling process by aid of a current of water. So that a large percentage of the energy of the combination is forcibly abstracted.

In the new Otto engine the heat of combustion is divided between three volumes; one of these, it is true, is at a very high temperature, but the other two are at the temperature of the surrounding objects, and after the explosion they attain a degree of heat only about half that of the exploded mixture of the Lenoir engine. This reduction of the temperature leads to another loss in dynamic effect, for if the tension is reduced to one-half, the volume of the compressed gas is doubled. At the temperature thus reduced, the loss by radiation and the contact with the sides of the cylinder, diminishes in a proportion greatly to the advantage of this motor.

It would be desirable in Otto's engine to relieve the cylinder entirely of the combustion products after they have acted on the piston, if they could be replaced by the same volume of air. The same theoretic effect would be obtained at a less temperature, and as the loss by radiation and by contact would be less the useful effect would be augmented.

Some details of the engine require description. M. Otto provides at the bottom of his cylinder a little cylindrical chamber of fifteen or twenty centimeters in length. At the bottom of this cylinder is the opening by which enter in succession the air and the explosive mixture of gases. The advantage of such an arrangement is evident; the mixture is preserved more intact than it would be in the larger cylinder and the ignition is managed with more certainty.

We have shown how that in the working of this engine, its action varies for

four successive strokes. Thus it is necessary—

1st. That during the first stroke, the cylinder should admit during the first half, air and during the remainder the explosive mixture.

2d. That at the end of the second stroke the explosive mixture should be ignited.

3d. That at the end of the third stroke, and during all of the fourth, a valve should open to permit the escape of the products of the combustion and the residual gases.

To accomplish these results M. Otto has furnished his engine with a counter shaft moving with half the angular velocity as the main shaft, thus making a single revolution for the four strokes of the piston.

This counter shaft carries a rod communicating with a slide at the bottom of the cylinder which is held open during a

fourth of a revolution or during one stroke, and so exposes the gas flame to the atmosphere.

A coupling upon this shaft also carries a cam which regulates the flow of gas from its reservoir.

By the same connection also is opened the valve for the admission of the explosive mixture. The coupling slides along the shaft and is guided by a regulator. When the motion is accelerated beyond certain limits the cam is so displaced that the inlet gas-valve does not open, and the explosion of the gases is omitted till after the next four strokes.

The little gas burner, which ignites the mixture at the proper moment, is so placed as to be subjected to the pressure of three atmospheres, and therefore requires a special adjustment.

Another coupling and cam opens the valve for the escape of the residual gases.

## FOUNDATIONS.\*

By JULES GAUDARD, Civil Engineer.

From Proceedings of the Institution of Civil Engineers.

### I.

THE Author proposes to give a description of the principal methods resorted to in making foundations. Although these methods are applicable, in general, to every sort of construction, they possess a special importance in the case of large bridges, on account of the greatness of the load, the instability of the soil, and the amount and flow of water to be contended with. It is not sufficient, moreover, that the bed of the river and the ground upon which the foundations of a pier rest are firm, they must also be secured against scour, as only hard rocks are unaffected by a rapid stream. To ascertain the nature of the soil on which foundations are to be laid borings are generally taken, but they sometimes prove deceptive, owing to their coming on some chance boulders, or upon some adhesive clays which, without being firm, stick to the auger,

and twist it, or arrest its progress, and the specimens brought up, being crushed and pressed together, look firmer than they really are. To remedy these defects some engineers have adopted a hollow boring tool, down which water is pumped and reascends, by an annular cavity between the exterior surface of the tool and the soil, with such velocity that not only the detritus scraped off by the auger, but pebbles also, are lifted by it to the surface. This process is rapid, and the specimens, which are obtained without torsion, preserve their natural consistency.

On stiff clay, marl, sand, or gravel, the safe load is generally from 55 to 110 cwt. on the square foot, but a load of 165 to 183 cwt. has been put upon close sand in the foundations of the Gorai bridge, and on gravel in the Loch Ken viaduct and at Bordeaux. In the bridge at Nantes there is a load of 152 cwt. to the square foot on sand, but some settle-

\* Translated from the French by L. F. Vernon-Harcourt, M.A., M. Inst. C.E.

ment has taken place. Under the cylindrical piers of the Szegedin bridge in Hungary, the soil, consisting of clay intermixed with fine sand, bears a load of 133 cwt. to the square foot; but it was deemed expedient to increase its supporting power by driving some piles in the interior of the cylinders, and also to protect the cylinders by sheeting outside. Cylinders, moreover, sunk to a considerable depth in the ground, possess a lateral adherence, as is evident from the weights required for sinking them, which adds greatly to the stability of the foundations. Taking into account this auxiliary support, the loads of 159 and 117 cwt. per square foot, at the bottom of the cylinders of the Charing Cross and Cannon Street bridges respectively, are not excessive. On a rocky ground the Roquefavour aqueduct exerts a pressure of 268 cwt. to the square foot.

Foundations may be classed under two heads:—(1) Ordinary foundations, on land, or protected from any considerable rush of water; (2) Hydraulic foundations, in rivers, or in the sea.

#### ORDINARY FOUNDATIONS.

When the ground consists of rock, hard marl, stiff clay, or fine sand, the foundations can be laid at once on the natural surface, or with slight excavation, and with horizontal steps where the ground slopes. At the edge of steep descents, with dipping strata, it is necessary to find layers which will not slip, or, if there is such a tendency, to strengthen the layers of rock by a wall, especially when it is liable to undergo decomposition by exposure to the air, or to use iron bolts uniting the layers of rock. On ground having only a superficial hard stratum resting upon a soft subsoil, buildings have sometimes been erected by merely increasing the bearing surface, and lightening the superstructure as much as possible; but generally it is advisable to place the foundations below all the soft soil. On an uneven surface of rock a layer of concrete spread all over affords a level foundation. Sometimes large buildings have been securely built on quicksands, of two great thickness to be excavated, by the aid of excellent hydraulic mortar, and by excavating separately the bed of each

bottom stone. Such a building will be stable if its pressure on the foundation is uniform throughout, and if it is placed sufficiently deep to counterbalance the tendency of the sand to flow back into the foundations. Instances of this class of foundations are to be found in sewers built on water-bearing sands, which sometimes give rise to as much difficulty as foundations built in rivers; as for example in the net-work of London sewers, and in the Metropolitan railway. The flowing in of sand with the water in pumping, and consequent undermining of the houses above, was prevented in these cases by constructing brick or iron sumps for the pumps in suitable places, surrounding them by a filtering bed of gravel, and using earthenware collecting pipes, thus localising the disturbance. In the construction of the Paris sewers, where the water-bearing strata could not be excavated on account of the running in of the sand, the upper portion only of the culvert was first constructed (Fig. 1). A little trench was then dug

Fig. 1.

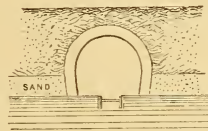


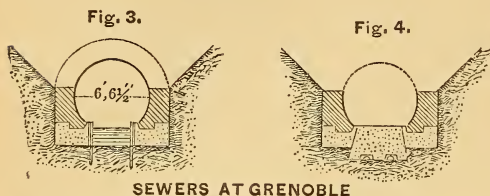
Fig. 2.



SEWERS IN PARIS

out at the bottom, each side being supported by interlaced boards, and this trench was then pumped dry in lengths of about 110 yards at a time. When one length was dry, a second row of boards was beaten down on the top of the first row, and at last it was possible to excavate the soil in lengths of thirteen feet, carefully shored up, in which the lower portion and the invert could be constructed, completing the section of the culvert (Fig. 2). In this manner a culvert, nine feet ten inches wide, twelve feet six inches high, and 2,950 feet long, was constructed in eighty-five days. The excavations for a sewer at Grenoble were executed from below upwards, in order to insure a continuous flow of the water, and the sides were built as the excavation proceeded, a trench supported by boards conveying the water, and the invert was begun when the piers were finished, commencing at the upper part;

semicircular troughs of cement having been placed at the bottom of the excavation to afford continuous drainage, over which a layer of quick-setting concrete was deposited (Figs. 3 and 4).

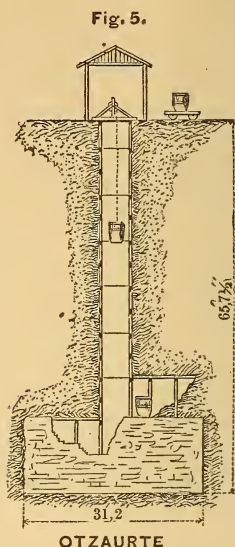


SEWERS AT GRENOBLE

One means of reaching a solid foundation without removing the upper layer of soft soil is by piling, but piles are liable to decay in many soils. In Holland, buildings on piles of larch, alder, and fir have lasted for centuries, whilst in Belgium large buildings have been endangered by the decay of the piles on which they rest. Sometimes columns of masonry support the superstructure, but, being placed farther apart than piles, it is necessary to connect them with arches at the surface for carrying the walls. Piers, however, of viaducts supporting a heavy load must be carried down in one mass to the solid ground, as in the case of the viaduct of Otzaurte, on the Rio Salera in Spain, where it was necessary to get through sixty-five feet of silty clay to lay the foundations of a pier thirty-one feet long by thirteen feet wide. In order to avoid getting out so large an excavation in one piece, a well was dug, four feet wide, and extending across the whole width, thirteen feet, of the pier, so as to divide it into two equal portions (Fig. 5). A chamber, nine feet ten inches high, was then driven at the bottom, like a heading, as far as the limits of one-half of the foundation of the pier, and built up with masonry. The other half was similarly dealt with, and the excavation and masonry were carried up in successive lifts of nine feet ten inches. The central well served as a means of access for pumping out the water, for the removal of earthwork, and for the supply of materials.

To avoid the difficulty and expense of timbering deep foundations, a lining of masonry is sometimes sunk, by gradually excavating the ground underneath, and weighting the masonry cylinder, which is eventually filled in with rubble stone,

concrete, or masonry, and serves as a pier.



OTZAUARTE

In India a similar system has been followed for centuries for sinking wells. The linings are made in radiating courses of bricks or stones; the first length, from five to ten feet high, being put on a circular wooden framework placed on the surface of the ground. Very fine sand is used for filling the joints, except for the two or three top courses, which are laid in mortar, and the whole construction is tightly bound together. It is then gradually sunk by a man inside undermining it, and another length is placed on the top. As these operations are generally conducted in the silty or sandy bed of rivers which become dry in summer, there is no running water to contend with, but water percolates into the excavation, and then the natives use a "jham," by which they remove the earth from under water. Although the external diameter of the wells has been sometimes limited to five feet, the advantage of larger dimensions in securing a vertical descent has been always recognized. At the Western Jumna canal rectangular linings were adopted with advantage. At the Solani aqueduct hollow cubes with sides twenty feet long, and at Dunowri oblong or square linings, thirty feet long and twenty feet deep, and subdivided into three or four compartments, were used.

When the stratum of soft soil is too

thick for the foundations to be placed below it, the soil must be consolidated; or the area of the foundation must be sufficiently extended to enable the ground to support the load. The ground may be consolidated by wooden piles; but in soils where they are liable to decay, pillars of sand, or mortar, or concrete, rammed into holes previously bored, may be used. Artificial foundations are also formed by placing on the soft ground either a timber framework, surrounded occasionally by sheeting, or a mass of rubble stone, or a layer of concrete, or a thick layer of fine sand spread in layers eight to ten inches thick, which, owing to its semifluidity, equalizes the pressure. A remarkable example of this method was afforded in the restoration, in 1844, of the arched way at the Phillippeville gate, at Charleroi, where the old pile-work foundations had twice given way. A trench was dug  $3\frac{1}{4}$  feet deep and  $3\frac{1}{4}$  feet wider than the construction on each side, and inclosed by little walls. Into this cavity was put very fine sand, moderately wetted, then a layer of concrete, twenty inches thick, and upon this the masonry was built, which has stood perfectly. When the bottom of the excavation is silty, it is advisable to throw a thick layer of sand over it before driving piles, as the sand gives consistency to the silt.

A heavy superstructure is partially supported on a soft foundation by the upward pressure due to the depth below the surface to which it is carried, in the same manner that a solid floats in a liquid when it displaces a volume of water equivalent to its own weight. According to Rankine a building will be supported when the pressure at its base is  $wh \left( \frac{1 + \sin \phi}{1 - \sin \phi} \right)^2$  per unit of area, where

$h$  is the depth of the foundation,  $w$  the weight of the soft ground per unit of volume, and  $\phi$  the angle of friction.

Mr. McAlpine, M. Inst. C.E., in building a high wall at Albany, U.S.A., succeeded in safely loading a wet clay soil with two tons on the square foot, but with a settlement depending on the depth of the excavation. In order to prevent a great influx of water, and consequent softening of the soil, he surrounded the excavation with a puddle trench, ten feet high and four feet wide,

and he also spread a layer of coarse gravel on the bottom.

When the foundation is not homogeneous it is necessary to provide against unequal settlement, either by increasing the bearing surface where the ground is soft, or by carrying an arch over the worst portions.

#### HYDRAULIC FOUNDATIONS.

Under this head are comprised all foundations in rivers, and where running water has to be contended with.

Foundations are laid upon the natural surface where it is rocky, also on beds of gravel, sand, or stiff clay secured against scour by aprons, sheeting, rubble stones, or other means of protection. When the foundations are to be pumped dry, dams are resorted to if the depth of water is less than ten feet, and are specially applicable to the abutments of bridges, where the water is less deep and rapid and the bank forms one side of the dam. The dam can be made of clay, or even earth free from stones and roots, with slopes of 1 to 1; the width at the top being about equal to the depth of water when the depth does not exceed three feet in a current, or ten feet in still water. The leakage of a dam and the danger of breaches increase rapidly in proportion to the head of water. At Hollandsch Diep a great dam of sand, protected from the waves by fascines, had to keep out a head of water of twenty-three feet at high tides from the foundations. M. de la Gournerie constructed a temporary dam of silt, 4,265 feet long, at St. Nazaire, in 1849, to protect the shed of the floating dock. The dam was thirteen feet high, four feet wide at the top, with a pitched slope of 1 in 3 towards the sea, and an inner slope of 1 in 5.

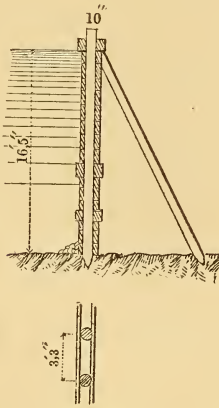
Concrete makes a solid dam, but it is expensive to construct and difficult to remove. A masonry dam 328 feet long was built at Lorient in 1857.

A cofferdam with a double row of piles takes up less space and is less liable to be worn away or breached than an earth-work dam. At the Auray viaduct a dam was made of two rows of piles, with boards filling up the spaces between the piles, the center of the dam being filled with well-punned silt, and protected outside with rubble stones. It supported

the pressure of a head of water of from five to eleven feet; its average cost was £1 0s. 10d. per lineal foot. The width of a cofferdam is often as great as the head of water; but if the cofferdam is strutted inside, so that the clay merely acts as a watertight lining, the width need not exceed from four to six feet. In a cofferdam of concrete at Marseilles constructed for the basin of the graving docks, the widths were calculated at 0.45 of the total height, the maximum width has thus attained twenty feet.

In building the viaduct of Lorient, on a foundation dry at low water, a single row of strutted piles,  $3\frac{1}{4}$  feet apart, planked from top to bottom on both sides, was used (Fig. 6), and the space

Fig. 6.



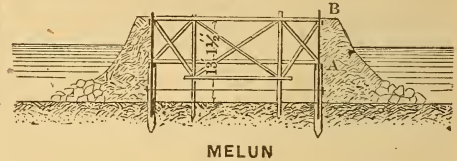
LORIENT

between the planking, ten inches wide, was filled with silt pressed down. When the filling is so much reduced in thickness the planks are carefully joined, and the clay is mixed with moss or tow, or some times with fine gravel or pounded chalk. As water leaks through joints and connections, the ties are placed as high up as possible, and the bottom is scooped out or cleaned before the clay is put in. When the sides of the part to be inclosed are sufficiently close they may be effectually supported by a series of stays, as was done in making the dam for the construction of the apron of the Melun dam (Fig. 7), where struts were put in at intervals of  $16\frac{1}{2}$  feet.

The Grimsby Dock works, and the Thames Embankment works, furnished

examples of cofferdams constructed to bear the pressure of a great head of water. For constructing the Zuider Zee locks on the Amsterdam Canal a circular dam, 525 feet in diameter, was erected, consisting of a double row of sheet piling, the piles being one foot square and fifty feet long, with walings attached.

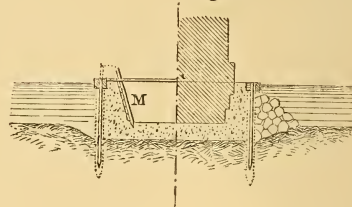
Fig. 7.



Eventually, in consequence of accidents, a third row was added, and the dam further strengthened by sloping banks of sand on both sides, the outer slope being protected by clay and fascine work. The head of water against the dam was occasionally twenty feet.

If large springs burst out in an excavation they must be either stopped up with clay or cement, or be confined within a wooden, brick, or iron pipe in which the water rises till the pressure is equalized, and then it is stopped up as soon as the masonry is sufficiently advanced and thoroughly set. If, however, there is a general leakage over the whole bottom of the excavation it must be stopped by a layer of concrete, incorporated with the foundation courses (Fig. 8).

Fig. 8.



Cofferdams or troughs of concrete had been used on a large scale at Toulon and Algiers for the construction of repairing docks.

Where there is not space for a clay dam, timber sheeting well strutted and caulked is used. For instance at the Custom-house quay of Rio de Janeiro a dam of square sheet piling, with counterforts of cross sheet piling, and made watertight by hoop iron let into grooves in each pile, served to support the press-

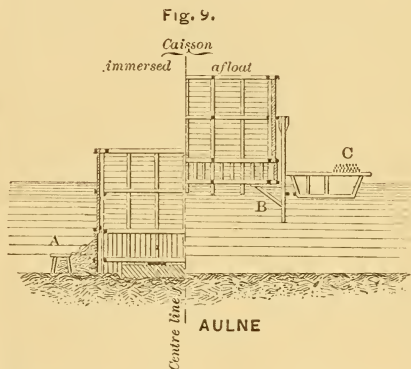
ure of about twenty-three feet of water. A similar structure, however, at the West India Docks was floated away by an equinoctial spring tide, owing to the want of tenacity of the ground. When the head of water is under five feet, tarred canvas is sufficient to keep it out, the canvas being weighted at the bottom, and nailed to a beam at the top. It is in every instance advisable to take out the earthwork for foundations in lengths.

In the construction of the Victoria Docks a metallic cofferdam was used, which was very easily displaced by floating.

Hollow timber frames without a bottom, and made watertight at the bottom after being lowered by concrete or clay, are suitable in water from six to twenty feet deep on rocky beds, or where there is only a slight layer of silt. This method was resorted to by M. Beaudemoulin, between 1857 and 1861, at the St. Michael, Solferino, Change and Louis Philippe bridges at Paris. The timber frame at the St. Michael bridge was fifteen feet nine inches high, 125 feet long, and nineteen feet eight inches wide at the base, with a batter of 1 in 5; the uprights were six inches square, and  $6\frac{1}{2}$  feet apart; the framework was made of oak, and the planks of deal (nine inches by three inches), the spaces between them being covered by small laths nailed on to the planks. Fourteen crabs placed on four boats supported the framing, and let it down as it was built up; this was weighted with stones to sink it on the foundations prepared by dredging, and the planks were then slipped between the walings and beaten down lightly. A toe of rubble stone outside supported the pressure of the concrete inside. The whole operation took ten days, and in one month the masonry was finished up to the plinth. The caisson, including erection, cost £560.

The caissons of the bridges at Vienna, sunk twelve feet below water level, cost £2 18s. 6d. per lineal yard of circumference. At the Point-du-Jour viaduct the caissons were 131 feet long, and from twenty-six to thirty-three feet wide, and from twenty-one to twenty-six feet high. The long sides were put together flat on the ground, and were lifted up to allow of the short sides being fixed to them. A few hours sufficed for depositing the

caisson in its place. M. Picard in reconstructing the Bezons bridge, after the war of 1870, used caissons in two portions, as the lower portion had to remain, whilst the upper portion was only needed for a time. Some nails and straps fastened the two parts together. A layer of clay was placed under the rubble toe outside, to prevent leakage between the concrete and the planks. This expedient was first adopted by M. Desnoyers, in order to pump dry the foundation which he carried down into the clay, so as to build masonry walls on the bottom without using concrete. At the Aulne viaduct in Brittany, MM. Desnoyers and Arnoux made a caisson seventy-five feet six inches by thirty-four feet nine inches, and nearly twenty-three feet high (Fig. 9), and, with the excep-



tion of the bottom portion, caulked beforehand. When it was deposited the bottom planks were slid down between the lower set of walings, and a toe of puddled clay "A," protected from the rush of the current by canvas, was put round the bottom outside. The caisson was so watertight that a Letestu pump working two or three hours each day kept the foundations perfectly dry. When the caisson, put together on a stage supported on eight boats, was ready for depositing, the sluice doors of the Guily-Glas dam were opened, lowering the caisson till the projecting pieces "B" touched the ground, and by cutting the beams fastening these projections to the boats, the boats were set free. As the tide rose the caisson floated, and the boats were attached to its upper part, which, by lightening, lifted it sufficiently for the projecting pieces to be taken off. The depositing was completed by open-

ing the sluices of the dam at high water, and as the water fell the caisson, weighted with rails, sank on the dredged bottom. Thus by the help of water alone a mass weighing seventy-four tons was safely and accurately deposited. The cost of one caisson was £740; and the cost of the foundation below low water did not exceed £1 12s. 6d. per cubic yard. At Lorient large caissons, from twenty-three to twenty-four feet high, were employed; but an interior dam of concrete forming a permanent part of the foundation was used instead of an external toe of clay. At Quimperlé M. Dubreil made the caisson watertight by a dam of clay inside, which necessitated a somewhat larger caisson, but admitted of the removal of the timber.

When a limit to the space occupied is immaterial, as on the large American rivers, a sort of double-cased crib-work dam is frequently adopted. M. Malózieux has given various details of this class of work, such as the cofferdam in Lake Michigan to obtain the water supply for Chicago. A caisson 200 feet long and 98 feet wide, inclosed by double watertight sides from thirteen to nineteen feet high, was used at Montreal on the St. Lawrence. The interval between the two sides was about eleven feet wide, and planked at the bottom so that the caisson could be floated into place. When the caisson was sunk, piles were driven in holes made in the bed of the river to keep it in place, and the bottom was made watertight by a lining at the sides of beams and clay. These kinds of caissons are only suitable where the bottom is carefully levelled. Although iron caissons are generally used for penetrating some distance into the soil, there are instances of iron caissons being merely deposited upon the natural bed. M. Pluyette founded one of the large piers at Nogent sur-Marne in a plate iron caisson, which weighed about seventy tons, and cost £3,600, with a bed of concrete in it ten feet thick and protected by rubble stone. Its dimensions at the bottom were seventy-two feet by  $37\frac{3}{4}$  feet, with rounded corners and a batter of 1 in 15, 29½ feet high, including a length of five feet, which could be removed when the work was finished. The thickness of the plates was from  $\frac{1}{8}$  inch to  $\frac{1}{2}$  inch, and it

was strutted inside with timber. The same system was adopted at Brême, where caissons sixty-nine feet by  $16\frac{1}{2}$  feet were used for the four ordinary piers, and the width increased to  $42\frac{1}{2}$  feet for the pier on which the bridge turns; their height was  $11\frac{1}{2}$  feet, and the thickness of the plates  $\frac{3}{8}$  inch. The operation of sinking the caissons from a floating stage occupied about seven hours. A layer of concrete nine feet thick was spread over the bottom and left for twelve weeks to set before the water was pumped out.

The methods employed for laying foundations in the water, either on the natural surface or after a slight amount of dredging, have next to be considered.

A rubble mound foundation is sometimes employed for dams where any settlement can be repaired by adding fresh material on the top; also for landing-piers in lakes by solidifying the upper portion with concrete, and in breakwaters where a masonry superstructure is erected on the top. Such a method, however, is not suitable where a slight settlement would be injurious; and in the sea the base of the mound is generally less exposed to scour than in a river.

Another method consists in sinking a framing, not made watertight, inside which concrete is run, and the framing remains as a protection for the concrete, and is surrounded by a toe of rubble. If the framing is of some depth iron tie-rods are put in by divers after the bottom has been dredged, to enable the framing to support the pressure of the concrete. When piles can be driven the framing is fixed to them. The piles, five to eight feet apart, have a double row of walings fixed to them, between which close planking is driven, from ten to fourteen inches wide, and from three to five inches thick, and sometimes, when the scour of a sandy subsoil has to be prevented, the planks are grooved and tongued, or have covering pieces put on by divers, or are driven in close panels. The insufficiency of a simple framing of planks for foundations on running sand was demonstrated by the destruction of the Arroux bridge at Digoin, and the Gue-Moucault bridge over the Somme by the flood of September 1866, in spite of the fascines and

rubble stone protecting their piers, owing to the washing out of the underlying sand through small interstices by the rapid whirling current. The cost per superficial yard of a casing formed with piles and planks is about £ 1, including the cost of driving  $6\frac{1}{2}$  feet.

Open framing is sometimes used for inclosing a mound of rubble stone. These mounds require examination after floods, and renewing till the mound has become perfectly stable.

In permeable soils foundations of concrete inclosed in frames are frequently employed, as, for instance, for the foundations of the Saints Pères, Jena, Austerlitz, and Alma bridges at Paris; but in silty and watertight soils foundations in excavations pumped dry are preferable.

The bed of the Rhone at Tarascon, consisting of sand and gravel in which piles are difficult to drive, is subject to scour in floods to a depth of 46 feet. Foundations, however, were laid there, at considerable expense, by frames with double linings, ten feet apart, in which large blocks were placed with unhewn stones on them; the ground was then dredged inside the frames to twenty-eight feet below low-water level, and 260 cubic yards of concrete were deposited in twenty-four hours.

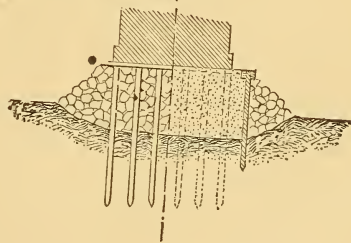
Lastly, concrete can be deposited *in situ* for bridge foundations; and though concrete blocks are only used in sea works, bags of concrete, like those at Aberdeen, by Mr. Dyce Cay, M. Inst. C.E., might be sometimes employed, instead of rubble stones, for forming the base of piers or for preventing scour.

Piles are used where a considerable thickness of soft ground overlies a firm stratum, when the upper layer has sufficient consistency to afford a lateral support to the piles, otherwise masonry piers must be adopted.

The piles are usually placed from  $2\frac{1}{4}$  to 5 feet apart, center to center, and the distance is occasionally increased to  $6\frac{1}{2}$  feet for quays or other works only slightly loaded. Sometimes under abutments or retaining walls the piles are driven obliquely to follow the line of thrust. The Libourne bridge rests on piles  $2\frac{1}{4}$  feet apart, and driven about forty feet in sand and silt. At the Voulzie viaduct, on the Paris and Mulhouse railway, some

piles were driven eighty feet without reaching solid ground, and the ground between the piles had to be dredged, and replaced by a thick layer of concrete. Piles which have not reached firm ground sustain loads nevertheless, owing to the lateral friction, as, for instance, in the soft clay at La Rochelle and Rochefort piles can support 164 lbs. per square foot of lateral contact, and 123 lbs. in the silt at Lorient. On the Cornwall railway, viaducts were built upon piles, sixty-five to eighty feet long, driven, in groups of four fastened close together, by a four-ton monkey with a small fall. A timber grating is fastened to the top of the piles, or a layer of concrete is deposited, as at Dirschau, Hollandsch Diep, and Dordrecht; or both grating and concrete, as the grating distributes the load and strengthens the piles. Planking is sometimes put on the framing which distributes the pressure, as at London Bridge, but it is considered objectionable as it prevents any connection between the superstructure and the concrete, and increases the chance of sliding. The space between the piles from the river bed to low water is sometimes filled with rubble stones, and sometimes with concrete (Fig. 10), which is less liable to disturbance. When the ground is very soft a filling of clay has been preferred on account of its being lighter than concrete.

Fig. 10.



A mixed system of piling and watertight caissons, of rubble filling and concrete, was adopted at the Vernon bridge. After the piles had been driven the spaces between them were filled up to half the depth of water with rubble stones: a caisson ten feet high was then placed on the top, and a bottom layer of concrete deposited in it. In a month's time the interior of the caisson was pumped dry, the heads of the piles cut

off, and the filling with cement concrete completed to low-water level. The caisson was cut off to the level of the grating as soon as the pier was well above water. The foundation cost altogether £14 8s. per square yard of base of the pier.

The heavy ram of Nasmyth moved by steam, with a small fall, but giving sixty to eighty blows per minute, enabled piles to be driven thirty-three feet in a few minutes, and with much less chance of divergence or jumping than in driving with less powerful engines. In certain soils, in which there is a momentary resistance during pile-driving, it has been proposed to bore holes in which the pile should be afterwards driven.

At St. Louis the annular piles,  $3\frac{1}{4}$  feet in diameter, made of eight pieces of wood, used for guiding the pneumatic caisson, were driven by the aid of the hydraulic sand-pump working inside, the invention of Mr. Eads, M.Inst. C.E.

The load that a pile driven home and secure from lateral flexion can bear may be estimated at from one-tenth to one-eighth of the crushing load, which varies between 5,700 and 8,500 lbs. per square inch. Thus, taking a fair load of 710 lbs. per square inch, a small pile of seven inches diameter will bear about twelve tons, and a pile of eighteen inches diameter will bear about eighty tons, and a pile to bear the load of twenty-five tons used as a unit by M. Perronet should be about ten inches in diameter. According to M. Perronet a pile can support a load of twenty-five tons as soon as it refuses to move more than  $\frac{3}{8}$  inch under thirty blows of a monkey, weighing eleven cwt. ninety lbs., falling four feet or under ten blows of the same monkey falling twelve feet. At Neuilly, however, M. Perronet placed a load of fifty-one tons on piles thirteen inches square, but driving the pile till it refused to move more than  $\frac{3}{16}$  inch under twenty-five blows of a monkey of the same weight falling  $4\frac{1}{2}$  feet; but such a load is unusual. At Bordeaux the driving was stopped when the pile did not go down more than  $\frac{3}{16}$  inch under ten blows of a monkey, weighing 1,100 lbs., falling about fifteen feet, but one of the piers settled considerably, the load on a pile being twenty-two tons; whereas at

Rouen, by insisting on M. Perronet's rule, no settlement occurred.

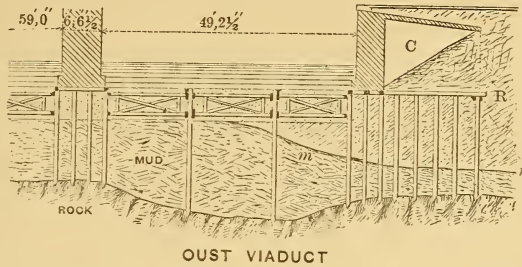
From experiments made at the Orleans viaduct, M. Sazilly concluded that piles might support with security a load of forty tons when they refuse to move more than  $1\frac{1}{2}$  inch under ten blows of a monkey weighing fifteen cwt. and falling about thirteen feet.

Various formulæ have been framed for calculating the safe load on piles, which are quoted in a paper by Mr. McAlpine, M. Inst. C.E., on "The Supporting Power of Piles," and in a Paper on "The Dordrecht Railway Bridge," by Sir John Alleyne, Bart., M. Inst. C.E. If Weisbach's formula is applied to M. Perronet's rule it appears that, assuming a safe load, the limiting set of the pile might be  $3\frac{1}{4}$  inches instead of  $\frac{3}{8}$  inch for ten blows; and the formula shows that large monkeys should be adopted in preference to a large fall, and in this it agrees with practice for preventing injury to the piles.

In order to provide against the danger of overturning in silty ground, the ground is sometimes first compressed by loading it with an embankment, which is cut away after a few months at those places where foundations are to be built. At the Oust bridge it was even necessary to connect the piers and abutments by a wooden apron, which, for additional security, was surrounded by concrete (Fig. 11). The abutment was made hollow to lighten it, and the embankment, "R," had compressed the silty ground to *m n*. The foundations cost £23 1s. 7d. per superficial yard for depths of from thirty-three to forty-three feet from the natural surface to the rock, or £1 16s. 10d. per cubic yard, a high price due to the difficulties met with and the bad weather. At the bridge of Bouchemaine, near Angers, the bending of the piles, which traverse about twenty feet of silt, was stopped by surrounding them with great masses of rubble stones.

Occasionally foundations on piles have failed or suffered great sets or lateral displacements. At the Tours bridge, many arches have fallen at successive times; holes in the foundations had to be refilled with lime, and below certain arches a general bed of concrete was afterwards established.

Fig. 11.

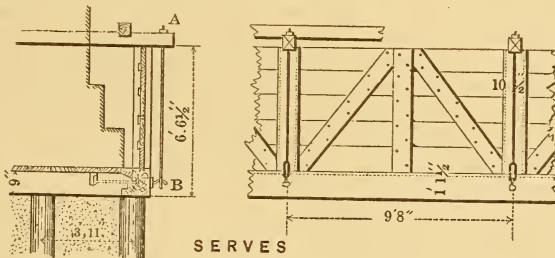


OUST VIADUCT

Floating caissons require a bottom carefully levelled on which to be lowered. Labeleye, in 1750, deposited the caissons of old Westminster bridge on the dredged bottom of the river; but usually this kind of caisson is deposited on piles cut off to one level. These caissons have oak bottoms and movable sides of fir, and enable the masonry piers built inside to be lowered on piles previously driven. The oak bottom serves as a platform for the pier, and the movable fir sides can be used again for other caissons. At Ivry, with only two sets of movable sides, the contractor was able

to put four caissons in place in one month. The bottom, which consists of a single or double platform, has timbers projecting underneath which fit on to the rows of piles. The movable sides are sometimes made in panels which fit into groves both in the bottom framing and in upright posts, placed about ten feet apart, which are tenoned at the bottom, and kept in place at the top by transoms going across the caisson. The different parts of the sides are tightly pressed together by the bolt, A B (Fig. 12). In other instances, as at the bridge of Val Benoit over the Meuse, the sides

Fig. 12.



SERVES

butt against the vertical sides of the bottom, against which they are pressed by keyed bolts, D, placed at intervals of five feet (Fig. 13). The caisson is kept near the shore whilst the first courses of masonry are being built in it; it is then on a favorable opportunity floated over the site of the pier prepared to receive it, and is gradually sunk by letting in water.

At the Bordeaux bridge the caissons had a height of twenty-six feet, and were divided in cases by transverse rods. This work, which comprises seventeen arches, was founded in a great depth of water, about the year 1820, by the engineers Deschamps and Billandel.

In sea works the laying of foundations

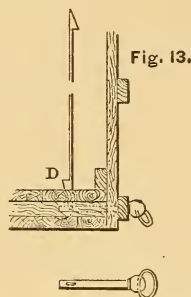
in the water is managed differently. Thus artificial blocks of concrete may be deposited by the help of divers, as at Dover pier; or much larger masses may be moved by powerful machinery, as, for instance, blocks of 150 to 200 tons put down at Brest in 1868, and at Dublin by Mr. Stoney, M. Inst. C.E. For small landing piers, and for piers of bridges in rivers not exposed to the breaking up of ice, artificial blocks or metallic frameworks may be placed under water on the top of timber piles cut off level, a plan adopted by Mr. Maynard, M. Inst. C.E., on a foundation of screw piles.

Screw piles were introduced by Mr. Mitchell, M. Inst. C.E., for securing buoys. They can be applied with ad-

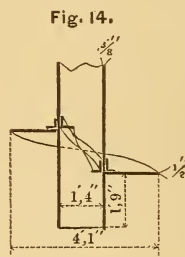
vantage to the construction of bollards and beacons, on account of the resistance they offer to drawing out; but as in the process of screwing down the ground is more or less loosened, judgment must be used in employing them for mooring or warping buoys. In foundations for beacons they should be screwed down from fifteen to twenty feet below the level to which the shifting sand is liable to be lowered. Even when all cohesion of the ground is destroyed in screwing down a pile, a conical mass, with its

apex at the bottom of the pile and its base at the surface, would have to be lifted to draw the pile out. The resistance to settlement is also increased by the bearing surface of the screw; and the screw pile is accordingly to be preferred to an ordinary pile in soft strata of indefinite depth, or when the shocks produced by ordinary pile-driving are liable to produce a disturbance. The screw pile has likewise the advantage of being easily taken up.

Screw piles have been principally used



VAL BENOIT



in England and in the United States. They have usually one or two spirals projecting considerably from the shaft, these spirals being cylindrical for soft ground and conical for hard ground, and either of wrought iron or of cast iron. The shaft may be of wood or, by preference, of iron, which must be pointed at the end for hard ground, but cylindrical and hollow when the ground is soft. The screw will penetrate most soils except hard rock; it can get a short way into compact marl, through loose pebbles and stones, and even enter coral reefs. A screw pile turned by eight capstan bars, twenty feet long, each moved by four or five men, with a screw four feet in diameter, passed in less than two hours through a stratum of sand and clay more than twenty feet thick, the surface of which was about twenty feet below water, and dug itself to a depth of about one foot into an underlying schistous rock. At the Clevedon pier screw piles penetrated hard red clay to depths varying between seven and seventeen feet, and although the screw had a pitch of five inches they rarely went down more than three inches in one turn. Mr. W. Lloyd, M. Inst. C.E., has recorded an unsuccessful use of screw piles, which in the shifting sandy bed of a South

American river became twisted like a corkscrew, and were overturned in the first breaking up of the ice. At Hamburg screw piles, in sets of three and joined at the top, are used as bollards. The piles are hollow wrought-iron tubes,  $\frac{3}{8}$  inch thick, furnished with a screw both inside and out, with a pitch of one foot (Fig. 14). To screw them down two capstans were used to pull the two ends of a rope wound round the head of the pile, the force transmitted to the pile being thirty times that applied at an arm of the capstan, and towards the close, when the pile had been forced down nearly thirteen feet, seven men were required to work each capstan. At the commencement each turn of the screw produced a descent of ten inches, and hardly nine inches at the end. A vessel struck, in 1852, against one of these bollards, and broke off the top without shifting the piles.

Piles with discs, used in the first instance at the Leven and Kent viaducts, by Mr. Brunlees, M. Inst. C.E., differ little from screw piles except in the method of sinking them. This operation was performed by sending a jet of water down a wrought-iron tube inside the cast-iron pile, which washed away the silty sand from underneath the disc

and caused the pile to descend. The sinking cost about 2s. 6d. per lineal foot, whereas at Southport pier, where water was obtained from the waterworks, and ten piles were sunk per tide, the sinking only cost 4½d. per lineal foot. Wooden piles, with a cast-iron shoe carrying a disc, might easily be sunk in the same manner, the water pipe being carried eccentrically through the disc.

Hollow wrought-iron piles have also been forced down by blows of a monkey, in silty and sandy ground interspersed with boulders, to a depth of about sixty feet; the thickness of the piles being about one-nine inch, and the diameter 19⅝ inches. On the Cambrian railway, Mr. Conybeare, M. Inst. C.E., drove wooden piles down below the surface, by means of a lengthening piece of cast iron on the top, a piece of wood or lead being interposed between the monkey and the cast iron.

Large masonry piers carried through thick layers of soft ground to a solid bed may be constructed by various methods, and constitute the best kind of foundation in such a situation.

The method of cased wells is suitable

where the silt is sufficiently compact and watertight to admit of pumping the well dry, and where the depth of water is small and can easily be kept out by a cofferdam or a caisson without a bottom. The well is sunk by the ordinary methods of sinking wells or driving headings in silty ground. At the Auray viaduct, a muddy stratum, twenty-six feet thick, was got through by this method. In building the abutment of a bridge over the Vilaine, in Brittany, resting on six pillars carried down fifty feet below the water-level, the same method was adopted; but for the lower portion of the excavation a smaller framing had to be sunk inside. A pillar fifty feet deep requires about twenty days for the excavation, and twelve days for building the masonry. The cost is from £1 16s. 10d. to £2 9s. per cubic yard of foundation complete. When the pier is so wide as to render the strutting difficult, an outer ring can be first lowered, which serves afterwards as a casing for excavating the inner portion. Where permeable gravel or very liquid silt has to be traversed it is necessary to resort to tubular foundations.

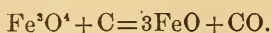
## SOLID STEEL CASTINGS.

BY M. FERDINAND GAUTIER, OF PARIS.

Journal of the Iron and Steel Institute.

WHEN steel is cast in an iron ingot mould, or a mould of any kind, usually the metal after cooling is not entirely sound. Cavities of a more or less rounded shape are seen inside, apparently caused by a gas escaping from the mass. Mr. Henry Bessemer, the first among metallurgists, has demonstrated that these blow-holes were filled with oxide of carbon, and this view has since been entirely confirmed.

Refining produces oxide of iron,  $\text{Fe}_3\text{O}_4$ , which reacts on the carbon according to the formula:



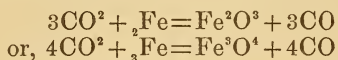
The protoxide of iron passes into the slag, and the oxide of carbon remains in dissolution within the metal. But the

solubility of the oxide of carbon diminishes rapidly during the cooling period, and some gas bubbles remain imprisoned in the solidified mass.

When these blow-holes are altogether inside, and do not burst through the crust, they remain silvery white; it is a simple solution of continuity, and to get rid of them it is sufficient to weld the metallic parts by reheating and the use of a hammer or rolls. What becomes of the carbonic oxide? Is it re-incorporated with the metal? This has not been determined yet. But the fact is that when rolled steel bars, drawn from honey-combed ingots, are broken, no trace is found of this kind of defect.

When the blow-holes communicate with the outside, and the sides of the

ingots are pierced with small holes, well known to the steel manufacturers, the color is no longer a silvery white; they assume more or less the colors of the rainbow, and even become black. This takes place because the carbonic oxide of the blow-holes is transformed by the contact with the air into carbonic acid, and oxidation of the metal occurs.



according to the temperature when the reaction takes place.

We know, from Mr. I. L. Bell's works, that the oxidation of iron by carbonic acid begins at about 300° C. (570 F.), and is very strong at a high temperature.

Hammering and rolling do not entirely eliminate these blow-holes, as a perfect welding of the metallic particles is prevented by the presence of oxide of iron. There remain some black streaks, which sometimes penetrate to a depth of  $\frac{1}{10}$  inch (2 millim). In order to correct these surface defects, the welding must be done by allowing the piece to undergo heating at as high a temperature as possible; the steel is there covered with sand, and hammered vigorously. The oxide of iron which prevented welding is combined with silica, and forms a silicate which pressure easily expels. This is a general practice in the manufacture of fine steels.

It will be seen that it is an easy matter to remove blow-holes when the steel has to undergo mechanical elaboration; but it is not so with castings, and it is very important to prevent the formation of these blow-holes when sound pieces are wanted, and pieces the resistance of which can be relied upon.

All steels have not the same tendency to produce blow-holes while solidifying. Generally, the more a steel is carbonized, the better it will flow while casting, and fewer blow-holes will form. On the contrary, the more a steel is decarbonized, the less fluid it will be, and more blow-holes will form. It is probable that hard steels keep better their oxide of carbon in dissolution, or else it escapes more freely on account of the greater fluidity of the metal.

This property of highly carburized steels has led to the casting of thin

pieces without blow-holes. A very hard steel, with about 1.5 per cent of carbon, is cast in thoroughly dry moulds. The castings thus obtained are left for several days in an oxidizing atmosphere, or even in contact with a bed of oxide of iron or zinc, as in the manufacture of malleable iron. Very strong products are obtained in this manner, but they must be very thin, and even then they are far from being without blow-holes. As is the case with malleable iron, thick pieces are out of the question, as decarburizing goes little by little, from molecule to molecule, and through a solid body. If the pieces were too thick, the outside would become oxidized before there was a thorough decarburization of the mass. This very interesting process is carried on with success at Sheffield.

We have to speak now of the German manufacture of steel without blow-holes. Every one will remember those splendid ingots, clean-fractured, growing in weight at each successive exhibition, first beginning with two tons, and finally reaching 45. The Krupp ingots, and the cast wheels and bells of Bochum, certainly astonished the metallurgical world for some time. The process of manufacture was kept a most profound secret, and has not yet been published.

More than six years ago, the Terre-Noire Steel Works found out, by reasoning rather than by practice, the process of the German works, and the improvements they have made have radically transformed the result.

It seems well proven now that the German products without blow-holes are obtained by an addition of a very siliceous pig just before casting; and thus they are found to be highly carburized, and the chemical analysis shows a rather considerable portion of silicon. To find an explanation of the result, we must go back to the theory of the Bessemer process. It is well known that the combustion of the silicon takes place during the first part of the operation; there is no flame, or rather, there is a series of brilliant sparks; the yellow sodium band, characteristic of all flames, is not seen; no oxide of carbon is formed while there remains any silicon to be oxidized; the silicon decomposes the oxide of carbon, or, which is the same, prevents it from forming; therefore, if

blow-holes are filled with oxide of carbon, they will be made to disappear by the addition of silicon



The carbon is deposited and dissolved in the steel, and silica is formed. Experience shows that steels treated in this manner are generally without blow-holes.

In order to prove this theory, the following experiment can be made. A bath of siliceous pig is formed in a Siemens-Martin furnace, and refined by successive additions of iron or steel. Tests are taken at short intervals. At first, these tests are quite sound, but they become full of blow-holes. If a chemical analysis is made, it is found that the first honey-combed test contains no silicon, while the preceding tests contained some.

If the products obtained in this manner are without blow-holes, the quality is rather inferior, in spite of the long annealing they usually undergo after casting. We will analyse the several causes of this inferiority.

1st. These steels are very highly carburized: the pig being generally poor in silicon, the operator is led to charge a rather large quantity so as to be sure that it will act effectually.

2d. The silica produced by the chemical reaction that destroys the blow-holes is, indeed, generally combined with oxide of iron in the bath; but the slag is slightly fluid, and remains in the steel, which is thus made pasty. It lessens its strength; it may even make it crumble when trying to work it hot.

3d. There remains in the final product an excess of silicon, which, in addition to the excess of carbon, tends to lower its quality.

This influence of silicon on pigs and steels has been anything but clear for a long time, and it may be said that even now it is not perfectly known. I think it useful, at any rate, to speak here of the curious experiments made by the late Wenzel Mrazek, of the School of Mines at Příbram (Bohemia).

Silicium always had the very worst reputation in metallurgy. Karsten, whom the Germans modestly call the immortal, was the first to assert that silicon gave to iron a special red-short quality (faul-brüchig) with a peculiar

fracture—an earthy fracture. This opinion was allowed to spread without any disputing until lately, when Mrazek showed that the action attributed to silicon should be ascribed to the silica found in the silicate mixed with the iron; for if metallic silicon of good quality is added to a certain quantity of iron, the original qualities of the metal are in no point changed. This view is much more logical from a chemical standpoint; for it is well-known that in the refining period silicon disappears first of all; it would be necessary to suppose that after refining is done the silicon is again reduced in spite of the oxidizing influences, passes back into the metal, and makes it red short. It is, therefore, impossible to believe there is any free silicon in the iron in a notable quantity; but the material found is silicate, such as that of steel without blow-holes of which we have just spoken.

But if silicon is harmless in a soft metal, it is far from being so in a product containing carbon. In a preceding paper, I spoke of the incompatibility of carbon and phosphorus in steel; and of the necessity of suppressing carbon when using phosphorus. Mrazek's experiments prove that there is also incompatibility between carbon and silicon in steel. The simultaneous presence of carbon and silicon causes brittleness, hot or cold, while a cast metal, containing slight traces of carbon only, will bear up to 7 per cent. of silicon, and still roll well at red or white heat, and will even weld perfectly well. Therefore, if a quantity of silicon is wanted in a cast steel (and there must be some to ensure perfect soundness) it will be necessary, in order to obtain a good product, not to entirely suppress the carbon, but at least to lessen the quantity considerably.

At the Terre-Noire Steel Works, the manufacture of steel without blow-holes has been perfected by using a silicide of manganese and iron, which gives to the product remarkable qualities. The silicon prevents blow-holes by decomposing the oxide of carbon, which is in dissolution, and tends to escape during solidification. The manganese reduces the oxide of iron, and prevents a further production of gases by the reaction of the oxide on the carbon. We have seen

above that in the decomposition of oxide of carbon by silicon, silica was produced, and afterwards a silicate of iron, which remained interposed within the steel. The manganese allows the formation of a silicate of iron and manganese, which is much more fusible and passes into the slag. For this reason, the metal is not altered by a foreign body, and this is a capital point.

In order to show plainly the complete structural difference between steels without blow-holes obtained with silicon alone and those obtained with an alloy of silicon and manganese, Mr. Pourcel operates in the following manner. In a porcelain tube he places two receptacles, one holding steel by silicon alone, and the other steel by an alloy of silicon and manganese. A current of chlorine is passed until all the iron is removed in a state of chloride. It is seen then that in the first receptacle, there remains a net work of silicate of iron preserving

the original form of the pieces, while the steel by alloy leaves no residuum.

We already know that an excess of manganese remaining in a steel improved the quality of it; we learn from Mrazek's experiments that a slightly carburized steel containing free silicon and manganese at the same time, can be excellent. A steel bearing

Silicon.....	1.50
Manganese.....	0.76
Carbon.....	0.18

is very strong and rolls perfectly. It is therefore useless to be much concerned about the excess of manganese or silicon that may remain in the steel cast in this manner.

More than 500 charges of steel without blow-holes were analysed and tested at Terre-Noire, and below are the results obtained in tensile strength with cast metal of three different qualities :

CHARGE IN TONS (2,240 lbs.) PER SQUARE INCH.  
ELONGATION MEASURED ON A FOUR-INCH TEST BAR.

		Raw Metal, coming out of the Mould.			Metal, reheated and cooled slowly.		
		Tons per Square Inch.			Tons per Square Inch.		
		Elastic Limit.	Breaking Load.	Elongati'n per Ct.	Elastic Limit.	Breaking Load.	Elongati'n per Ct.
Hard Steel for Projectiles.	No.						
	948...	21.0	40.4	1.7	24.8	52.0	7.25
	966...	19.8	39.0	2.0	22.4	51.0	8.50
	1,355...	22.0	34.0	2.0	23.6	51.5	8.00
	1,502...	24.3	33.2	1.0	27.3	57.1	7.40
	1,737...	21.2	35.0	1.7	24.2	59.0	7.00
Strong Soft Steel.	1,872...	22.0	38.9	1.5	25.6	56.0	3.40
	1,545...	23.2	40.5	2.0	24.2	52.0	12.2
	1,558...	21.7	43.7	3.3	25.3	51.0	14.0
Very Soft Steel.	1,563...	20.6	41.8	2.5	24.3	51.9	17.5
	2,078...	10.3	32.7	12.5	16.0	34.5	28.5
	2,081...	12.7	34.4	12.4	18.8	35.6	25.6
	2,149...	13.3	33.2	12.5	18.0	35.4	24.3

This metal is in no respect similar to the steel without blow-hole castings made until now; it can be hammered, and rolls without flaws; it resists hard blows, and when soft will stand considerable bending before breaking; in a word, in the form of a moulded piece, it

possesses the same properties as a rolled and hammered metal.

This brings us to speak of a very remarkable paper by M. Chernoff, an engineer at the Aboukoff Steel Works, St. Petersburg. This paper is on the structure of steel. A steel ingot is a

body coming more or less rapidly from a liquid to a solid state, and preserving a more or less crystalline texture. There is one general rule, and that is, that all metals possessing a crystalline texture are brittle, as for instance antimony, bismuth, zinc in ingots; while a confused and irregular texture corresponds to the greatest resistance. Steel is not an exception to this rule, and if a fracture is crystalline, the piece is very brittle. Fortunately, this defect can be modified in several ways.

1. By simple re-heating to cherry red, when an ingot with coarse fracture, and completely lacking the requisite strength, will suddenly be transformed after ordinary cooling into a fine grained and strong product.

2. By hammering at a sufficiently high temperature cast steel loses its crystalline structure, provided this hammering is continued, while cooling takes place, down to a certain point varying with the different steels, and beyond which the metal preserves its whole power of resistance. If hammering was left off at a high temperature, and the metal abandoned to itself, the crystalline structure would re-appear, and with it the lack of strength.

3. The rapid cooling of a cast metal also destroys the crystalline state: this was observed in wrought iron armor plates.

Steel, then, seems to behave like an exceedingly concentrated dissolution of salt easily crystallizable, the crystallization of which is prevented by certain precautions only.

For Mr. Chernoff, as well as for us, unwrought cast steel is neither softer nor weaker than a steel of the same grain forged at a suitable temperature.

Of course, we are speaking of steels without any defects, cracks, or blow-holes, or else a comparison would no longer be possible.

Mr. Chernoff took a coarse-grained cast steel ingot and had it cut lengthwise into four parts. One of the quarters was transformed directly, on a lathe, into a test bar. The second was heated to a bright red, forged under a steam hammer, the forging being stopped whilst the piece was yet rather hot. The third piece was heated up to the point at which the hammering of the preceding

piece had been left off, and then was allowed to cool freely. The fracture showed a very fine grain, very similar to that of the forged piece. These two quarters were also transformed into test bars.

The results of the traction tests were as follows:

In tons per square inch.	Breaking Load.	Elongation.
No. 1. Untouched ingot.....	38.5	2.3
No. 2. Forged ingot.....	45.5	5.3
No. 3. Ingot reheated and cooled in air.....	43.0	16.6

We believe, like Mr. Chernoff, that it is possible to have a steel cast directly just as strong as if it was hammered, provided that the metal be regularly without blow-holes, and crystallization done away with.

On Mr. Chernoff's part, this is a theoretical intuition, resulting from an enlightened study of a material. With us it is more than an opinion, for we bring a practical realization.

The very interesting fact that cast metal may have a higher density than forged and rolled metal has not yet been pointed out, yet at Terre-Noire it was ascertained that this density varied from 7.8 to 7.9, while that of rolled steel never went beyond 7.81. It would seem, from this experiment, that the rolling process causes not only a different arrangement of the molecules in reference to one another, but also a slight increase of volume. The question is now, in presence of these two facts—1st. that a cast steel may be more dense than a hammered one; 2nd. that its strength may also be superior. What can be the use of the compression of liquid steel?

Compression applied to steel was tried simultaneously, 12 years ago, at Terre-Noire and at Manchester by Sir Joseph Whitworth. The first results obtained on the Continent were such as to cause the process to be soon abandoned and forgotten. Two years ago new experiments were made in many places; but it seems well proved now that there is nothing to be done in this direction.

At Manchester, on the other hand, it is said that very interesting results were obtained: the compressed metal would bear 43 tons per square inch, with 32 per cent. elongation on a 2-inch length (which corresponds to 20—22 per cent.

on 4 inches). How are we to explain this difference? Undoubtedly the *modus operandi* is not the same, for in France and in Prussia no such result was ever reached.

It is to be regretted that, two years ago, during the visit paid at the Manchester works, the members of the Iron and Steel Institute were not enabled to get any idea of the efficiency of the process, otherwise than by a walk in a deserted workshop; the explanation of this great difference of results between two neighboring countries applying the same process could then have been found.

Compression cannot seriously modify density, for when the cast metal is perfectly sound, it possesses a density higher than that of forged metal. But it might very well happen, that, at the time of solidification, crystallization is stopped by a powerful compression, and the metal acquires the properties, similar to those of forged product. But at any rate, if compression can, in skilful hands, give good results, these results can be obtained in another way, a simpler one, and I believe a surer one; I mean the process I have just explained, in the name of the Terre-Noire Company. The first practical application of the metal without blow-holes, now manufactured at Terre-Noire, is due to the genius and perseverance of Mr. Euverte, the skillful director.

The use of hollow projectiles bursting inside a hip, after having penetrated through the armor, has, with an equal power of penetration, great advantages on solid projectiles. They burst into pieces both numerous and dangerous; they shake, dislocate, and break the inside lining to a great extent, and the resulting leakages cannot be stopped up.

Chilled cast iron balls being low priced compared with forged steel ones (six or eight times cheaper), and the manufacture of them much more rapid, a great economy could be realised, from the military stand point, by using them.

Gradatz, Finsponge, Terre-Noire, Châtillon, Piombino, and Palliser, furnished samples, but without any good results; the projectiles split and break in normal firing, when the plates they strike against are rather thick.

In oblique firing, even against comparatively thin walls, the chilled iron

balls break at 20 deg., and at 30 deg. they are pulverized.

This deformation of the projectile diminishes its penetrating power, since the *force vive* is spent in sterile efforts to break, and, according to Capt. Noble's formula:

$$\frac{WV^2}{2g} = \pi RKB^2$$

it is this *force vive* that measures the penetrating power with equal diameters. Furthermore, the cracks, which at first sight do not seem very hurtful, prevent a sufficient tension of the gas during explosion of the powder, and poor effects are obtained.

In spite of the seeming boldness in substituting cast for forged steel, in spite of the little faith of the ordnance men themselves, at this moment the Steel Works at Terre-Noire manufacture regularly 9½ inches projectiles capable of penetrating, at an angle of 30 degs., plates eight inches thick, with the relatively slow speed of 1,400 feet per second. The projectiles never break; some times the point is slightly bent. This is, I venture to say, the most severe test to which a cast metal can be subjected, for in the trials of which I speak, this cast metal showed itself superior to forged steel both in strength and regularity.

After this undisputed success of which you undoubtedly have heard, for it is now nearly a year old, Mr. Euverte asked himself the question whether the strains to which the metal is subjected in a cannon are not much weaker than when a projectile pierces an armor plate? It is true there is a difference, for in one case the metal is compressed and in the other it is drawn.

It is not known yet whether it will be possible to begin immediately the manufacture of cannons in one piece as was formerly done in cast-iron cannons for the navy and the defence of towns. But there is one idea which presented itself naturally, and is being studied even now,—it is nothing less than the replacing of the cast-iron body by a cast-steel one in coiled guns. Thus, a metal hardly able to stand a strain equal to ten tons, will be replaced by another requiring thirty-three tons at least to break it, supposing, for security's sake, that the softest metal was used.

Will the application of this new metal stop here? Decidedly not. You know that in the latest trials at Spezzia, the 100-ton gun was not able to force a projectile through a forged steel armor plate. It is but just to say that the plate was pulverized; but for some ordnance men this result is very interesting; they consider a ship is sufficiently protected when the outside plating is not pierced through by the projectile; they would even prefer to use plates thick enough to absorb the *force vive* of the ball while being pulverized, even if they should leave a portion of the ship bare, for it seems

very improbable that the same portion of the ship could be struck twice, considering the distances at which naval fights will take place with the new artillery. If the new cast metal is used for this purpose, the softest qualities only must be used, but so far, every circumstance points to a great result to be reached with enormous economy.

As to the different industrial applications, they naturally present themselves to every mind, and we might even say they will push themselves forward, bearing with them these two great advantages—solidity and economy.

## THE MAGNETIZATION OF STEEL TUBES.

By M. GAUGAIN.

Translated from "Revue Industrielle."

If a steel rod, neutral as regards magnetism, be introduced into a magnetized steel tube, and after a moment withdrawn, it will be found to be feebly magnetized in the same direction as the tube. But if while the rod is in the tube, both tube and rod be heated to about 300°C, and then left to cool, it will be found upon withdrawing the rod that the magnetism of the tube is much reduced, and the polarity of the rod is reversed.

I suppose that at the ordinary temperature, the rod assumes a polarity opposed to that of the tube during the time that it is within the tube, but upon being withdrawn friction is inevitably produced, and this reverses the polarity. It would seem that at the elevated temperature we have on the one hand the *inverse* magnetism of the rod, induced by the tube considerably augmented by the heat; and, on the other hand, the *direct* magnetization developed by the separation of rod and tube much weakened, the tube having lost much of its magnetism by the separation. The inverse charge therefore remains predominant.

Analogous efforts are produced when a magnetic rod is introduced into a tube that is not magnetic. At the ordinary temperature the tube upon being separated from the rod will be found magnetized in the same direction, but if

heated while together and allowed to cool before separating, the tube will be found to contain a charge the reverse of that of the rod.

It is not necessary in applying the heat to produce an inverse charge of magnetism, that either rod or tube should be in a neutral state. It is sufficient that they be unequally magnetized and in the same way; then if there is enough difference, the one with the weaker charge will be found with its poles reversed after separating them.

Now considering the case of a tube and rod in the neutral condition magnetized by Elias's process,—If the charge is imparted at the ordinary temperature, the two when separated are found magnetized in the same direction. This fact has been verified by M. Jamin.

The same result is obtained when the system is magnetized while at a temperature of 300° or 400°, if the rod and tube are separated immediately. But having charged the system at a high temperature and then allowed it to cool, the rod and tube being separated, exhibit opposite polarity; it is only in a particular case that their magnetism is in the same direction; the polarity varying with the bore of the tube, the coercitive quality of the steel, and the intensity of the current that charges them.

I have experimented with tubes of  $\frac{1}{4}$ ,

$\frac{1}{2}$ ,  $\frac{3}{4}$ , and 1 millimeter diameter; the exterior diameter of each was 10 and the length was 300 millimeters.

Rods and tubes were made of the steel known as *doux Petin-Godet*.

The following table exhibits the result of experiments with the tube of  $\frac{1}{2}$  millimeter bore.

I	M	M'	m	m'
3.4	+	4.6	+	8.0
7.5	+	20.0	+	22.2
14.5	+	56.0	+	21.0
20.0	+	80.0	+	27.0
29.0	+	80.0	+	30.2
38.0	+	87.2	+	34.0
			-	1.5
			-	2.5
			-	17.2
			-	23.2
			-	28.0
			-	29.5

The numbers in column I give the intensities of the currents employed.

Columns M and M' show the force of magnetism in the rod and tube respectively, when measured directly after charging, and before cooling.

Columns m and m' indicate the magnetic charges in rod and tube after cooling.

The + sign signifies the direction of the magnetism afforded by the current to either rod or tube at the ordinary temperature. The - sign indicates the reverse polarity.

An inspection of this table shows that the magnetism m of the rod which is *inverse* for the feeble current, 3.4, becomes *direct* when the intensity of the current augments; and that on the contrary, the polarity of the tube m' which is *direct* for the currents whose intensities are 3.4 and 7.5, becomes *reversed* with stronger currents.

These results may be regarded as the consequence of a simple fact stated in the beginning of this note. It appears from the above table that before cooling the system, the rod and tube are magnetized in the same way; that the initial charge M' of the tube overcomes that of the rod when the charge is feeble, and on the contrary, the charge of the rod surpasses and overcomes that of the tube, when the intensity of the current passes a certain limit. Accordingly it is the magnetism of the rod which should be inverted during cooling in case of feeble currents, and the polarity of the tube which should suffer change in the case of more energetic currents.

The differences exhibited by the columns M and M' for the different intensities point to the principle established by

M. Jamin, that the current penetrates to greater or less depth according as it is more or less energetic.

The experiments with the tubes of  $\frac{1}{4}$ ,  $\frac{3}{4}$  and 1 millimeter, gave results similar to those detailed above.

## REPORTS OF ENGINEERING SOCIETIES.

At a meeting in November, of the Liverpool Engineering Society, Mr. John S. Brodie, member, read a paper on "The Application of Blast Furnace Slag to the purpose of road-making." To begin with, Mr. Brodie explained that when soft stone is for "bottoming" it gradually works through the harder surface and has to bear the traffic in its place, for which purpose it was never intended. Consequently the road is rendered uneven and requires much mending. It was claimed for good blast furnace slag that when the bottoming and surface layers are both formed with it, the result is a durable roadway of uniform hardness throughout, and could be obtained at a less cost than the ordinary Mc Adam system. The mode of preparing the foundation for a road, and the subsequent formation of the successive layers of slag was next gone into, details of curvature and other matters being illustrated by drawings. It was shown that no foreign matter should be allowed among the slag, as it would diminish the durability of the roadway. The best slag for road making was stated to be that produced in smelting the Cleveland ore into gray or foundry iron. In conclusion prices of forming slag roads were given.—*Engineering*.

THE INSTITUTION OF CIVIL ENGINEERS.—At the opening meeting of the present session of this society, a paper was read on "The Progress of Steam Shipping during the last Quarter of a Century," by Mr. Alfred Holt, M. Inst. C. E., of Liverpool. With a view to direct the attention of members to the obligation voluntarily incurred, of doing all in their power to further the interests of the society by presenting good papers, the council have issued, under the title of "List of Subjects for Papers," a tractate which gives some interesting information respecting the funds under their control for the award of premiums. From this it appears that between £400 and £500 is available annually for rewarding the authors of "approved original communications." The awards take the shape of Telford and Watt Medals (which are the most highly prized), instruments, and richly bound books. There will also be adjudged this year the quinquennial Howard prize of the value of about £80 "to the author of a treatise on any of the uses or properties of iron, or to the inventor of some new and valuable process relating thereto," such author or inventor being a member or an associate of the Institution. This manifesto will doubtless have due effect in stimulating the members to uphold the high reputation the Institution has acquired as a disseminator of professional knowledge, and will it is hoped result in the

council being enabled to continue the publication of four volumes of "Minutes of Proceedings" annually.

**KING'S COLLEGE ENGINEERING SOCIETY.**—At a recent meeting of this society, a discussion was held on the several appliances for the pavements of roads. The discussion was opened by Mr. Guinness, who gave a general description of the macadamised road and the steam roller. Mr. Alliman gave some useful information in reference to the asphalt and wood pavements, and described the construction of roads in Russia. Mr. Samuel described the ancient Roman roads, and suggested that a macadamised road, consisting of broken granite and pitch, used in the same manner as the granite, would be very useful in places where the traffic was not too great. Professor Tennant, in summing up, said that the subject was of great importance, especially where so vast a population as that of London was concerned. He first referred to the alterations in transit which had resulted from the introduction of the locomotive, and as an illustration of the progress made, he stated that when he first came to London it took him thirty hours and cost him 30s. to travel the distance, which now occupied only four hours, at a cost of 10s. The Strand at that time was paved with boulder stone, similar to the present pavement of Scotland yard. Wood pavement was introduced about thirty years ago, but was soon discontinued on account of the exhalations which arose from it when saturated, and which tended to produce fever. The Professor then proceeded to examine the advantages and disadvantages of wood pavement. He said that four years was the longest time that it has been found to last in London, and that it was twice or three times as expensive as granite. The expense of the present granite pavement of the Strand was 17s. 6d. per square yard, but, formerly, when large stones were used, it only cost 15s. per square yard. It was found that horses could not get a thorough foothold on the larger stones, and resort was consequently had to the present material. Amongst the disadvantages which had presented themselves since the introduction of wood pavement was the increase in the number of accidents, which had occurred chiefly on the noiseless approach of Hanson cabs and other vehicles.

**LIVERPOOL ENGINEERING SOCIETY.**—At the first of the October meetings, Mr. J. E. Claudy, B.A.B.E., late sub-resident engineer on the San Paulo and Rio de Janeiro Railway, read a paper on "Railway Engineering in Brazil." He commenced by pointing out that in foreign countries an engineer's energies are not cramped by musty Acts of Parliament, local boards, and the red-tapeism too common in professional practice in this country. Abroad an engineer may delve and dig, hack and hew, with nature alone to oppose him. In carrying out a Brazilian railway an engineer has to look sharply after contractors and often do the work of an inspector or foreman. He ought, therefore, to have a good knowledge of the bricks, mortar, stones, and all materials

used in construction, as well as to be able to discriminate between good and bad work. He pointed out that most of the lime used for mortar was made by burning oyster shells, lime-stones being very scarce, although there was a brittle stone called "saibre" much resembling it which was often used if contractors were not looked after. Brazil has an area of three and a-quarter millions square miles, and only 1200 miles of railway working, whilst the United States, with a less area, has no less than 78,000 miles, and at the present time railway enterprise in Brazil is quite at a standstill, as there are no good roads or means of communication to act as feeders. Horses and mules are about the safest means of traveling. As an instance of mountain railways, the author called attention to the San Paulo Railway, which, in five miles rises from the sea level at Santos, to St. Paulo, 2600 feet above. This railway is worked on the wire rope system, the above distance being divided into four stages or "lifts," at each of which is situate a stationary engine. The heavy rainfall in Brazil, as in most tropical climates, has to be guarded against by allowing ample water ways all along the line of works—thirty inches in twenty four hours is not exceptional. He then went on to deal with the various engineering operations necessary in surveying, laying out, and constructing the railway, and pointed out that the lump sum contract system is seldom followed, the work being let and measured on a schedule of prices previously agreed upon. He concluded by pointing out that an engineer's position on a foreign railway is not a bed of roses, he having to undergo many hardships. The meeting was well attended, and among those present were noticed several Brazilian gentlemen.

### IRON AND STEEL NOTES.

**THE** New Zealand Titanic Steel and Iron Company have sent over some of their pig iron made from the metallic sands which lie along the shores of New Plymouth in Taranki. The company have two furnaces there, and cast their pigs 78 pounds each. The iron, which came consigned to a merchant firm in Wolverhampton, was tested for puddling purposes at the Shelton Bar Iron Company's Works, Stoke upon Trent. It is found that the waste was as much as 20 per cent. since it required 1 ton 3 cwt. 3 qr. and 14 pounds of pig to produce a ton of puddled bars. The quality however was declared to be excellent in both a cold and hot state, whilst it bore a tensile test of 1 to 1½ above the 22 tons per square inch, Admiralty test, for best bar iron. At Taranki the price of the pigs is about £3 10s. per ton. At that quotation the iron ought to secure for itself a market in Australia, where, just now a better business is being done in English pig iron than for many months past.

**PHOSPHOR STEEL.**—Without dwelling again on the nature and properties of the so-called phosphor steel, we may be allowed to remind our readers that the production of this

metal is still going on, showing it has been found possible to manufacture so-called steel rails containing as high as 3 to 5-thousandths of phosphorus, when, in the olden time, it was believed that 0.5-thousandth was too high a percentage. At the same time the steel thus produced rolls quite freely, and stands most ordinary tests remarkably well. The advantages of this metal are that it permits of the use of lower grade and cheaper ores, and the re-employment of old rails. These contain on an average 6 thousandths of phosphorus, but by a careful admixture with a pure pig iron a medium can be obtained which produces satisfactory results of a saleable character, the cost price of which is stated to be lower than that of the ordinary Bessemer.

**MALLEABLE STEEL.**—For some time past the manufacture of homogeneous or malleable cast steel has been attempted in a different direction, namely, by the compression of the molten metal. Sir Joseph Whitworth seems to be practicing this as a regular operation at his works in Manchester, but, from what scanty information we have gleaned as regards his process, it appears to consist rather in a mode of hydraulic forging than of compression proper of a liquid mass. Under a very severe pressure, steel is instantaneously solidified, and a solid, not a fluid, is then acted on by the compressing apparatus. We may add that Mr. Whitworth employs nothing but steel of the best quality, and smelted in the crucible. A French engineer, named Bouniard, late foreman at Terre-Noire, perseveringly tried the compression of fluid steel, and his plan was experimented with on a large scale at Revallier, Bietrix and Co.'s, at Saint Etienne, as well as at Terre Noire. No practical results were obtained.

Until very lately, erroneous ideas existed regarding the effects of compression on fluid metals, the density of which was supposed to be increased by such a process. Mr. Euverte's experience tends to discredit such an opinion, and to prove that the maximum of density can be better attained by casting the metal under the proper conditions. At Terre-Noire the homogeneous cast steel has a density of from 7.8 to 7.9, which is seldom reached by forged steel. No doubt but that in special cases, and for certain shapes of metal, the old system will still have to be followed, but that the new, simpler, cheaper, and more efficient one will supersede it in most other instances.

**HOMOGENEOUS STEEL.**—M. Euverte, the present intelligent director of the works at Terre-Noire, read a highly important and most interesting paper to the Société des Ingenieurs Civils, on the 4th of May last, on the subject of homogeneous steel, or steels without blows (*acier sans soufflures*), which completes in many particulars the paper presented to the Iron and Steel Institute at the last London meeting by M. Gautier, of Paris. This document enters so fully into details, giving the results of a series of long continued and carefully conducted original experiments, that we regret that we are not able to re-produce the whole of it. We commend it to the special notice of the steel

manufacturing community, confining ourselves to the summary of conclusions, which, we believe, have an important bearing on the future of this special branch of industry.

The question of homogeneous cast steel is not a new one, and took rise the very day when it became possible to produce large bodies of molten steel. The attainment of the desideratum, which consisted in being able to furnish castings superior in resistance to iron—nearly equal in fact to forged steel—was, indeed very attractive. The Germans were the first to take the matter up, and, as early as the year 1855, specimens of their manufacture were shown on exhibition. M. F. Krupp came forward with ingots of a gradually increasing size, and Bochum exhibited moulded specimens, among which solid wheels were especially conspicuous. Neither of these said a word about the physical properties, nor in regard to the chemical constitution of the metal, which was exciting much admiration, and they even took special care to mention nothing as to the mode of manufacture. It was, however, soon known that silicium had something to do with the results obtained. Mr. Bessemer, as early as 1861, took out a patent for its application. About this date, however, several English scientific men, among whom we find Fairbairn and Prof. Riley, if we are not mistaken, indicated the properties of silicium in combination with iron. Until the present period the practical details of the process remained a profound mystery, the general opinion being prevalent that it was practically impossible to cast homogeneous steel otherwise than very hard, and deficient in those ductile properties which make ordinary steel so valuable.

### RAILWAY NOTES.

**ALLOWING FOR RAIL EXPANSION.**—This is a point in practical railway building which, we see, was quite thoroughly discussed at the late meeting of the Master Mechanics' Association. In a paper by W. S. Huntington, the following table is introduced:

Length of rails, feet.	No. joints in a mile, one side of track.	Space for expansion, inch.	Fractions of an inch decimally expressed.			
15	352	.1026	1-64	.01562	1 2	.5000
16	330	.1090	1-32	.03125	9-16	.5625
18	293	.1228	1-16	.0625	5-8	.6250
20	264	.1363	1-8	.1250	11-16	.6875
21	251	.1434	3-16	.1875	3-4	.7500
28	188	.1914	1-4	.2500	13-16	.8125
30	176	.2044	5-16	.3125	7-8	.8750
36	146	.2465	3-8	.3750	15-16	.9375
40	132	.2725	7-16	.4375	1	1.0000

Among the reasons why it is best to be particular to have the rails the right distance apart at the joints are: If there is not room enough for expansion, the rails will bend to the form of a loop, causing death and destruction. And even if the compression is not sufficient to cause this, the effect on the traffic is destructive and causes breakages. If you are "out on the track" on a hot day, and the rails are "uncomfortably tight," and no trains in sight, you will be warned by the approach of one by the groaning and laboring of the track, as though it were a thing of life, and undergoing the most excruciating torture, or laboring like a ship in a storm at sea. The train may be two or three miles off, and out of sight, but you know it is coming by the cracking and snapping of the joints, as now and then a rail finds a little space and is thrust against its neighbor like a blow from a sledge. With this excessive compression on the rails and fish-bars, and the heavy rolling weight they are subjected to, the rails are strained and worked like a piece of tin bent back and forth between the thumb and fingers; and if there is a flaw or a weak spot it will soon amount to a crack and then break.—*Railway World.*

THE final result of railway working in 1876, as shown in the several reports to the Board of Trade on capital, traffic, and working expenses of the railways of the United Kingdom, by Messrs. Calcraft and Giffen, may be stated briefly as follows:—The extent of the system has been increased very little during the year, only 1.3 per cent.; but the double mileage has increased 3 per cent., showing the conversion of single into double lines. The capital at the same time has increased 4.4 per cent., but part of the increase is in nominal capital only; and the capital per mile open has increased 3.1 per cent. The ordinary capital has, however, increased more slowly than the total capital, or only 2.9 per cent. At the same time the traffic has increased 1.6 per cent., or rather less than the rate of increase of capital; but the working expenditure has increased more slowly still, or only 0.9 per cent.; so that the increase of real earnings is 2.4 per cent., more nearly approaching the rate of increase of capital. The receipts, expenditure, and net earnings per train mile have all decreased slightly. The result is (1) a slight diminution of the percentage of net earnings on the whole capital—viz., from 4.45 to 4.36 per cent., a reduction which would be still less in reality to those concerned, allowing for the increase in nominal capital only as distinguished from an increase in actual capital outlay; and (2) a rather larger but still not a large diminution of the dividend paid on the ordinary capital—viz., from 4.72 to 4.52 per cent., a diminution which would also be less if allowance were made for the infusion of merely nominal capital. These are the results in a year in which the increase of traffic has been at a lower rate than at any time since 1858, the average rate having been in that period 5.26 per cent., while last year it was only 1.59 per cent. They are also the results at a time when the rate of working expenses

is at a high level compared with the whole period prior to 1872. The result to railway capitalists in the circumstances cannot be deemed unfavorable on the average, though the average is, no doubt, composed in part of some unfavorable extremes. As regards the public use of railways, the facts stated as to the increase of third-class traffic, as well as of minerals and goods conveyed, would appear to show that use has been increased in 1876 in a greater degree than the return to the owners of the railway system.—*Engineer.*

MR. J. Rowland, Division Engineer of the Philadelphia and Atlantic City Railway, writes to the *Railroad Gazette*:—"It may be interesting to your professional readers to see this report of the most rapid railway construction on record. The Philadelphia and Atlantic City Railway is fifty-five miles in length. Ground was broken about April 1, 1877, and the first train was run over the road July 7. The deepest cut is 30 feet; deepest fill, 35 feet; largest single excavation, 40,000 cubic yards; embankment, 30,000 cubic yards. An embankment of 23,000 cubic yards, 1800 feet long, was made in one week from date of its commencement. The methods of construction are original with the officers of the road, and are of considerable interest to the profession. Five miles of track were laid in one day. There are over one hundred bridges and culverts; aggregate length of three longest, 1300 feet, one of them with 100 feet draw. The trial trip was made July 7, one and three-quarters miles of track being laid on that day in advance of the train, delaying it two hours; the road has 44,000 feet of wharf in Camden, built in two months, and has for its depots, offices and excursion house, Centennial buildings, known as Centennial Commissioners Building, La Fayette Restaurant, Board of Finance Building, Centennial Bank Building, Car Annex to Machinery Hall. The equipment of the road is, eight locomotives, forty-four passenger coaches, sixty freight cars. Gauge, 3½ feet. Average cost of grading, 10 cents per cubic yard of excavation and embankment. Total cost of construction and equipment, \$770,000. The line is as yet incomplete, but when brought to grade and completed according to engineer's plan it will be equal to any road in the United States for safety, speed, and comfort. T. F. Wurts, consulting engineer, constructed the road and organized the train force. Eight trains a day—four of them opposed—were run under his government, before the erection of telegraph line, at a speed of twenty miles per hour and with no great detention. The telegraph line is now in working order and superintendent appointed. Trains run through in two hours with no stops. A single train has carried 2300 passengers each way. When we see trains of twenty-nine passenger cars running, at a speed of thirty miles per hour, over a line of fifty-five miles in length which was commenced less than four months ago, the rapid stride of railroad progress is manifest. The engineer corps were employed night and day, sixteen hours being an average day's work for the consulting engineer."

## ENGINEERING STRUCTURES.

**BRIDGE BUILDING IN INDIA.**—The erection of the new bridge at Broach has been entrusted to Messrs. Thos. White & Co., the builders of the Government bridge over the Taptee. They in this contract are partners with Mr. G. H. Bayley, the engineer, who it will be remembered, so ably superintended the construction of the temporary bridge at Broach. Mr. Bayley resigns his position on the Bombay, Baroda, and Central Indian Railway in consequence of sharing in this contract. The estimate for the erection of the bridge is £40,000 less than the estimate of Sir John Hawkshaw. The Government seemed at first very anxious that the work should be done by a home firm, and it is due to the persistent representations of Mr. F. Mathew, the agent of the B. B. and C. I. Railway, that the Government were induced to permit the contract to be tendered for here. We congratulate the company on their success; and when it is remembered that the work will be done chiefly by the excellent staff which erected the present temporary bridge so rapidly and so well, under the able superintendence of Mr. Bayley, there can be no doubt that this splendid bridge, will be completed within the prescribed time and in a highly creditable way.—*Times of India*.

**A CENTRAL NEWS TELEGRAM SAYS:**—Operations connected with the submarine tunnel have already been commenced on the other side of the Channel, several pits having been sunk to the depth of about 110 yards. At the same time the French and English committees have definitely drawn up the conditions of working for the route. The property of the tunnel is to be divided in half by the length, that is to say, each company will possess half of the line, reckoning the distance from coast to coast at low tide. Each company will cover the expenses of its own portion. The general work of execution will be done on the one side by the Great Northern of France, and on the other by the London, Chatham, and Dover and South Eastern Railway Companies. All the materials of the French and English lines will pass through the tunnel in order to prevent unnecessary expense and the delay of transshipment; as in France and in England railway companies use each other's lines, and goods can pass from one line on another without changing vans. It is understood that an arrangement will be established for a similar exchange of lines between all the English and Continental railway companies. When the tunnel is completed the tunnel will belong to its founders, but at the expiration of thirty years the two Governments will be able to take possession of it upon certain conditions.

**SUBMARINE CABLES.**—Particulars of the submarine cables now in existence have been stated as follows by the Director of the Bureau International, at Berne, Switzerland. Private companies—Number of cables, 149; miles of cable, 59,547; miles of wire, 65,535. Government telegraphs—Number of cables, 420; miles of cable, 4,442; miles of wire, 5,725. Totals, 569; 63,989; 71,262. The last total shows the

extent of active wire as distinguished from the mileage of cable, some of them bearing as many as seven conductors. These figures give an average length of 112 miles for each cable, the average of the Governments being under 11, and that of the private corporations close upon 400 miles. The enumeration includes all wires laid in bays, gulfs, or estuaries on the coasts of the various countries, but excludes any laid across interior lakes or water-courses. In the north of Europe, the Government system of Norway embraces no fewer than 193 cables, each carrying one wire and only making up an aggregate of 233 nautical miles in length. In Sweden, besides the joint possession with Germany and Denmark of submarine cables joining the Scandinavian Peninsula with the European systems, the Government has four cables, of an aggregate length of 22½ nautical miles. Denmark has in its system twenty-nine different cables with a total length of 101 nautical miles. Holland possesses in all eighteen submarine cables, with an aggregate of 36 nautical miles, the longest being 16 miles. Although Russia possesses a telegraph second only in point of extent, in Europe, to that of the United Kingdom, the geographical formation of that vast empire is such that it only possesses three submarine cables, of 62 miles in all, besides its one-half share in the Crimea and Caucasus line. The cables of Germany in the North Sea and Baltic, and of Austria, in the Adriatic are forty-six in number, and 235½ nautical miles in extent. Turkey and Greece possess thirteen cables, of 147 miles in extent. Italy has twelve cables in all, one of them being 118 miles long. Spain has six, extending to 283 miles. The twenty-six cables of France are mostly short, though one of them—that from Marseilles to Algeria, 500 miles—is one of the longest in any national system. Great Britain with Ireland, has forty-nine cables, with a total length of 500¾ nautical miles, in addition to being owner of three cables to the Continent from the Norfolk coast, embracing 460 miles additional. Portugal is the only European nation which possesses no Government submarine telegraph.

The construction of most of the private lines has been due to British capital and enterprise. The Anglo-American Company has the longest submarine cable in the world (Brest to St. Pierre, 2,585½ nautical miles), and a group of five Atlantic cables in all; yet the total length of its cables is exceeded by the system of the Eastern Telegraph Company. The seventeen cables of the former extend in all to 12,315 nautical miles, the longest of the subsidiary lines, used to join those from Europe at the insular shore ends on this side, being that from St. Pierre to Duxbury, Massachusetts, with a length of 749 miles. The Eastern Company has, including the Eastern extension, a total of 21,883 nautical miles, being about one-third of the whole existing in the world. The original enterprise presented a total of thirty-nine cables and 14,502¾ nautical miles, and the extension nine cables and 7,381 miles. Next in point of extent are the systems of the West Indian and the Brazilian Companies, the former having nineteen cables with a total of 3,970 miles, and

the latter three cables and 3,866 miles. If the landings at Madeira and Cape Verde Islands are left out of view, the line from Portugal to Brazil may be looked on as the longest cable in the world. These two systems—the West Indian and Brazilian—are united by the lines of the Western and Brazilian Companies with nine cables of a total length of 3,750 nautical miles. Next to the French-Atlantic cable the longest unbroken line of submarine wire is the cable of the Direct United States Company, from Ballinskellig's Bay, County Kerry, Ireland, to Tor Bay in Nova Scotia, which is 2,420 nautical miles in length.—*Iron.*

## ORDNANCE AND NAVAL.

**THE QUICKEST PASSAGE ON RECORD BETWEEN ENGLAND AND AUSTRALIA.**—The *Melbourne Argus*, Sept. 3d, says—"The fastest passage on record from London to Melbourne has been made by the *Lusitania*, of the Orient Line. She arrived on the 8th ult., bringing English papers of three weeks' later date than those of the previous mail. The voyage has been performed in 40 days 6½ hours, inclusive of a detention of one day and seven hours at St. Vincent, where a call was made for coal, and the total time the steamer was under way was 38 days 23 hours and forty minutes. Some very fast steaming was done, and the average speed per day was 31½ miles, the greatest day's work being 344 miles. The *Lusitania* brought on 345 passengers, 68 of these being in the saloon. This quick passage of the *Lusitania* has excited much attention, showing, as it has done, that in the matter of steam communication *via* the Cape the colony may be better served by competition than by the subsidy of any particular line. The *Lusitania* goes home by the Suez Canal, which route has also been chosen for the homeward voyage of the *Whampoa*. It is interesting to note that, although the August mail was delivered in Melbourne a week before contract time, the time occupied between London and Melbourne was only one day less than the direct voyage of the *Lusitania*."

**ARMOR PLATES.**—Recently an armor-plate 16 feet long, 3 feet 6 inches broad, and 8 inches thick, and weighing 7 tons 16 cwt., was tested on board the *Nettle*, target ship, in Porchester Creek, Portsmouth, under the superintendence of Captain Herbert, of the gunnery ship *Excellent*. The plate was selected from the works of Messrs. C. Cammell & Co., Sheffield, as a sample of a number which have been manufactured by the firm for the turret ships *Agamemnon* and *Ajax*, at present in course of construction at Chatham and Pembroke. It is the invariable rule with the Admiralty, previous to accepting armor-plates from the manufacturers, to select a plate at random from a batch, and submit it to a practical test under fire. For the purposes of the trial the sample plate is bolted against a wood backing, which is carefully "dubbed" to fit the shape of the iron. It is then fired at from a short range, the shots being placed as close together as possible, the freedom, or compara-

tive freedom, of the intervening ridges from cracks determining the character of the plate. Should it pass the ordeal, as A 1 or A 2, the batch are accepted, but if of a lower order of merit, they are always rejected. The customary test consists of four shots, but in the present instance it was of a more crucial character. It consisted of nine spherical projectiles from the smooth-bore 68-pounder gun, the charge being 13 lbs., and the range 30 feet. All the shots fell within a space measuring 31½ inches by 27½ inches, and overlapped each other. The indentations ranged from 1.44 to 1.97 inches. After the fourth shot a slight crack appeared at the junction of Nos. 1 and 2, and subsequently a few other hair cracks appeared, but none were produced beyond the shot indents, and these were all insignificant. The iron exhibited great ductility under the racking test, and the plate on examination proved in every respect satisfactory. The following are the results of the nine rounds:

Indentations produced by	Diameter of impact.
1st.....1.72 inches.....	10 inches.
2d.....1.44 ".....	9½ "
3d.....1.62 ".....	10 "
4th.....1.56 ".....	10 "
5th... { 1.4 " }.....	in center to left 9½ "
6th.....1.88 ".....	10 "
7th.....1.9 ".....	10 "
8th.....1.88 ".....	10 "
9th.....1.97 ".....	10 "

A few days ago it was stated in *The Times* that Messrs. Cammell were about to conduct a series of experiments with steel plates on behalf of the Admiralty. These experiments are likely to prove of the very greatest importance, and will probably exhaust the subject so far as steel by itself, or in combination with wrought iron, can be applied to the protection of our ships of war. They will, therefore, naturally excite much interest among naval and military men. The experiments grew out of the recent trials of armor targets at La Spezzia, and the plates are being constructed for the purpose of ascertaining how far steel, or steel combined with iron, is better adapted for armor than the ordinary plates now adopted in the Navy. As the experimental armor is only 9 inches in thickness, the coming tests can be looked upon only as of a tentative character; but should the results obtained be sufficiently encouraging to proceed further, it is intended to manufacture both larger and thicker plates, and to submit them to the impact of heavier ordnance. The test plates, which are now being constructed at the Cyclops Works, are five in number, and are of the uniform dimensions of 10 feet long by 8 feet wide. Each plate is 9 inches thick and weighs nearly 13 tons. No. 1 is of wrought iron, the same as hitherto used, and will serve as a basis of comparison. No. 2 is of steel and, if possible, will be specially made of a quality and temper to resist shot without "starring" or cracking at a point distant from the part struck by the projectile. No. 3 is formed of "high" or hard steel, fused between two plates of wrought iron when the inside sur-

faces of the latter have been wrought by means of a specially constructed furnace to a welding heat. By this process a perfect union or weld between the steel and the iron is obtained. In a plate of this kind the hardest steel may be used, while the effects of starring may be reduced to the lowest limit of the protection which is afforded by the exterior surfaces of iron. No. 4 plate is formed of "high" steel between two "low" steel plates. The section will be like No. 3, but, instead of the two outside surfaces being iron, they will be made of a steel possessing the least possible amount of carbon. The above plates will be first tested, and will be afterwards followed by No. 5. This will consist of "high" steel, the surfaces having decarbonised, so that instead of steel, the surfaces will, to a certain extent, have become pure wrought iron. The great object sought to be attained in all these experiments is a material so hard that it will resist penetration without "starring" or breaking up—such a material as will, in fact, keep out or break up the shot without serious damage to itself. In addition to the above experiments there will be two new systems of belt fastenings tried at the same time. All the experiments will be made at Portsmouth, the 7 inch rifled Woolwich gun being used against the plates on the occasion at a range of 30 feet.—*London Times*.

**AVALANCHE AND FOREST COLLISION.**—*September 11th, 1877.*—The *Avalanche* was an iron sailing ship, full rigged; she was 1,161 tons, built at Aberdeen, in 1874, registered in London, and classed 100 A1. The *Forest* was a wooden, soft wood ship, of 1,422 tons, built at Hansport, Nova Scotia, in 1873, registered at Windsor, Nova Scotia, and classed A1. 10. Neither ship had been surveyed or certified by the Board of Trade.

The *Avalanche* had sailed from London, bound for Wellington, New Zealand, with a crew of thirty-four hands all told, having on board fifty-nine passengers, and a general cargo. She was provided with five boats, capable of saving 130 persons, two of them being life-boats. Three of the five boats were at davits and two on skids. She had two sets (whatever that may mean) of life-belts, and five life-buoys.

The *Forest* had sailed from London, bound to New York for orders. She was in ballast. She had a crew of 21 hands and not any passengers. She had three boats, one of them being a long boat, and the other two being galleys. The long boat was lashed keel downwards on the poop, and the two galleys were lashed keel upwards on the forecastle.

These two outward bound ships were both proceeding down Channel, and, at about 9 p.m., on the 11th September, 1877, were about fifteen miles S.W. of Portland. The night was not such as to prevent lights from being seen at a good distance; the wind was blowing a gale, force 8.

The *Avalanche* was, according to the report of the Wreck Commissioner, under foretop-sails, foresail, single-reefed mainsail, inner and outer jibs, foretopmast staysail, and spanker.

Of these, the mainsail only was reefed. The speed of the *Avalanche* was then from six to seven knots. The *Forest* was under reefed top-sails, whole foresail, and foretopmast-staysail. Her spanker was not set. The speed of the *Forest* was then about three knots.

A collision followed; the *Forest* ran her bow into the port side of the *Avalanche* nearly amidships. The inquiry has brought out many interesting facts that do not bear on the question of collision, and, as regards that question, which is the main one, we do not for an instant suppose that the case will rest where it is. It was a settled belief, and a settled practice of the sea, that where one of two crossing ships is required by law to keep out of the way of the other, the other ship should hold on. It is just as much the duty of the one ship to hold on as it is for the other to keep clear. In the present case, the *Avalanche* being the ship which had to get out of the way, tried to pass under the stern of the *Forest*, and the *Forest* being the ship required by the rules to keep her course, so altered her course as to run full tilt into, what was before the collision, the further side of the *Avalanche*. If the decision of the Wreck Court means that when a ship which is required to hold on, and is expected to hold on, does not hold on, and thereby brings about a collision, the blame is to be shared by the other ship which is trying to pass a-stern, the mind of the mariner will be in doubt, and this where no doubt existed before. We think the decision does create this doubt.

The next practical lesson we may learn from this collision is the utter uselessness of life-boats and life-saving gear in cases of emergency. In our articles on the loss of the *Atlantic*, and on the *Loch Earn Ville du Havre* collision, we wrote at full length on this topic, and would refer our readers to the remarks we then made. The loss of the *Avalanche* again proves that all the array of boats and life saving gear now required by law to be carried, are a delusion in a sudden emergency, and that to do as some hair-brained people wish, that is to say, to require large emigrant ships to carry still more boats, would be to add to danger by cumbering the ship's decks. The life-boats and boats of the *Avalanche*, though hung in davits, were useless; while the common boats of the *Forest* stowed on the poop and forecastle saved some life. Still, the fact that two ships, having amongst them boats enough to carry three times the number of people imperilled, saved only as many as could be counted on the fingers, and that one only of the eight boats of the two ships got to land, is a point in favor of our argument against trusting to increased boat accommodation for saving life on emergency.

Another practical lesson, and one which our shipowners will not fail to avail themselves of, is, that the British notion of the number of seamen necessary to man a ship is extravagant. The Court expressed their opinion as follows (we quote from the *Times*' report):—"The Court was not disposed to blame the owners of the *Forest* for having on board their vessel a small number of seamen, although it was only at the rate of one man and a-half to every

hundred tons." The Assessors had advised the Court "that American vessels can be worked with fewer hands than English vessels, because they have lighter ropes and larger blocks."

If, therefore, British shipowners will put lighter ropes and larger blocks on board, what is to prevent them from working their ships with reduced crews, after the manner of Nova Scotian soft wood ships? But is it a fact that vessels of the class of the *Forest* are so superior in their running gear, and tackles and ropes and blocks, and in their appliances for working ships, to British clipper vessels of the *Avalanche* class? There was a time when Yankee ships were a-head of British ships in all "notions" for working economically, and with that epoch, we imagine, must the advisers of the Court have been fully acquainted. It is, however, something quite new to those, like ourselves, who are posted up to the latest inventions and improvements in shipping, to hear that in respect of ropes and blocks, and appliances for saving labor, a Nova Scotian soft wood ship is a-head of English clipper ships. In no other respect does the one come near the other; but if the clear advantage of a reduction of a man, or a man and a-half per 100 tons is to be obtained, it is not likely that they will remain behind in this respect.

Another point is that both ships were classed ships, the *Avalanche* 100 A1., and the other A1. 10; and yet the highly-classed iron ship, in despite of her bulkheads, went down with every soul but three. This, again, shows what we have all along said: that lives are lost in classed ships. It may be thought to be absurd to make this observation in the present case, but it is not, for the following reason: when Mr. Plimsoll endeavoured to compel Parliament to adopt and enforce compulsory classification of all ships as a nostrum to prevent all shipwrecks, he used to parade the whole number of lives lost at sea, including those lost by collisions and strandings, and we think it only right to remind our readers of this now, and by quoting this terrible case of the *Avalanche* while it is fresh in mind, to show how utterly misleading were so-called facts brought forward to enforce the necessity for compulsory classification.

The last practical lesson to be learnt is the extreme endurance under certain circumstances of a soft wooden hull. The hull of the *Forest* floating bottom up defied the combined efforts of an ironclad ship and a number of gunboats. She was shot at with a heavy gun, she endured repeated explosions of several hundreds of pounds of gunpowder, and was at last towed in, much shattered it is true, to the Portland breakwater. It is only fair to assume that a foreign ironclad and foreign gunboats and their crews could not have made a greater impression than was made on her by Her Majesty's officers, seamen, gunners, and torpedoists. It took them many days to dislodge and then not to destroy the hull of the *Forest*, and the most valuable lesson is that if we wish to defend the mouths of our rivers from hostile attacks, the Government has but to lay its hand on all the soft wood ships in port and anchor a sufficient

number bottom upwards at the various approaches.

## BOOK NOTICES.

**FORMULÆ FOR THE CALCULATION OF RAILROAD EXCAVATION AND EMBANKMENT.** By JOHN WOODBRIDGE DAVIS, C. E. New York: Gilliss Brothers. For sale by D. Van Nostrand. Price \$1 50

This is a new edition of a good work on Excavation and Embankment Computation. It has already been somewhat widely used and as widely approved.

The method is simple, exact and easily learned by the average student. For the purpose of instruction, or for a practical guide to use in the field, this treatise, for reason of its compactness and the completeness of its demonstrations, may be regarded as a welcome addition to this already well supplied department of technical literature.

**THE WORKSHOP.** New York: E. Steiger. For sale by D. Van Nostrand.

No. 12 of this periodical is at hand. It maintains the high degree of excellence which has rendered it so widely acceptable to lovers of art whether students or artisans.

Among the more striking illustrations in the present issue we notice a Writing Table, Bronze Candelabra from the Opera House in Paris, and a Tea-Table Cover. The latter is printed in colors.

**STATISTICS OF MINES AND MINING.** Eighth Annual Report of ROSSITER W. RAYMOND, Ph. D., U. S. Commissioner of Mining Statistics. Washington: Government Printing Office. For sale by D. Van Nostrand.

The body of this Report is in three parts. Part I is in ten chapters devoted severally to the mining industries of the Western States and Territories; Part II describes in four chapters metallurgical processes; Part III describes mechanical operations belonging to metallurgy.

It is to be regretted that this report ends the labors of the Commissioner.

No public documents, we believe, have ever issued from the departments at Washington which afforded so much valuable information in proportion to the cost of obtaining and presenting it.

**LINEAR PERSPECTIVE AND MODEL DRAWING.** London: Macmillan & Co. For sale by D. Van Nostrand.

This is a brief but complete treatise on linear perspective. The subject is presented in thirty illustrated lessons, in the first four of which the learner is supposed to draw on the vertical plane, and thereafter is introduced by easy stages to the higher problems.

**MINUTES OF THE PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS.**

The published papers of the Institution received since our last issue are:

The Rajpootna (State) Railway, by Horace Bell, M.I.C.E.

The South Reserve Piers and Floating Land-

ing-Stage at Birkenhead, by Chas. Graham Smith.

The first is briefly a report of the first of the Indian Narrow-Gauge Railways. The gauge is one meter, 400 miles are completed.

Mr. Smith's paper, though short, is fully illustrated, and is a valuable addition to engineering literature.

SCIENCE SERIES, No. 33.

**M**ECANICS OF VENTILATION. By GEORGE W. RAFTER, Civil Engineer. New York: D. Van Nostrand. Price 50 cts.

This treatise has appeared in full in the pages of this Magazine. It is thoroughly practical in its character, and is furthermore a scientific presentation of the principles governing this important branch of sanitary engineering.

The public need yet to be instructed in the methods of securing health in the household, or at least securing immunity from those numerous ills which arise from bad ventilation and bad drainage. Contrary to the popular impression something more is required than knowledge of the bare fact that fresh air is desirable. It is yet to be generally learned that scientific skill is required to ventilate dwellings to the proper limit.

This little book proves this last statement in a concise and readable way.

**W**ATER SUPPLY OF SOUTH AFRICA AND FACILITIES FOR STORAGE OF IT. By JOHN CROUMBIE BROWN, LL.D. Edinburgh: Oliver & Boyd. For sale by D. Van Nostrand.

The Hydrology of South Africa by the same author, a notice of which appeared in our pages last year, gave a full account of the changes in the climate of this region with suggestions for remedy of the present aridity. The present work is designed to show that in many places in the colony where protracted drought affects the inhabitants a supply of water is at command sufficient for all ordinary wants.

The work is divided into Four Parts, and each Part into several Chapters.

Part I treats of Meteorology generally.

Part II is devoted to the Sources of Water Supply available for agricultural purposes in the Colony of Cape of Good Hope, and beyond.

Part III treats of the Supply of Water and facilities for Storage along the Western Coast of the Colony of Cape of Good Hope.

Part IV. Supply of water and facilities for Storage in Colonised lands adjacent to the afore-mentioned Colony.

The work evinces wide and careful reading on the part of the author, and although a large portion is chiefly of local interest, still a large part may be profitably read for the instruction afforded in Meteorology.

But districts, everywhere, suffering or likely to suffer from short supply of water are in present need of the information so carefully compiled in this work.

#### MISCELLANEOUS.

**F**ew of the persons who handle Bank of England notes ever think of the amount

of labor and ingenuity that is expended on their production. These notes are made from pure white linen cuttings only, never from rags that have been worn. They have been manufactured for nearly 200 years at the same spot—Laverstoke, in Hampshire, and by the same family—the Portals, who are descended from some French Protestant refugees. So carefully is the paper prepared that even the number of dips into the pulp made by each workman is registered on a dial by machinery, and the sheets are carefully counted and booked to each person through whose hands they pass. The printing is done by a most curious process in Mr. Coe's department within the Bank building. There is an elaborate arrangement for securing that no note shall be exactly like any other in existence. Consequently there never was a duplicate of a Bank of England note except by forgery. According to the *City Press* the stock of paid notes for seven years is about 94,000,000 in number, and they fill 18,000 boxes, which, if placed side by side, would reach three miles. The notes, placed in a pile, would be eight miles high; or, if joined end to end, would form a ribbon 15,000 miles long; their superficial extent is more than that of Hyde Park; their original value was over £3,000,000,000; and their weight over 112 tons.

**T**HE DECOMPOSITION THEORY OF STEAM BOILER EXPLOSIONS.—At the recent meeting of the American Academy of Sciences, an apparatus was shown at work, which proved that steam might be decomposed by simple heat into the constituent gases of water—oxygen and hydrogen. The heat employed was a little over ordinary redness, but did not reach whiteness. This experiment is of the highest value, as illustrating a possible cause of boiler explosions. The apparatus was very simple—a flask in which water was heated, a tube conveying the steam into a closed platinum crucible, where it was again heated by a spirit lamp, and a tube thence carrying the superheated steam and the liberated gases to an ordinary pneumatic trough, where the mixed gases were collected in a test tube, while the steam was absorbed. At the conclusion of the experiment, the gases thus collected were exploded by a lighted match, showing beyond question that they were the components of water. The experiment indicates that this explosive mixture of gases may be formed in a steam boiler. But it can only result from the most culpable carelessness. The boiler must, at least in part, be raised to a full red heat. Then cold water must be injected, for so long as steam and the gases are mixed, the latter cannot explode. The injection of water must condense the steam in the boiler before it cools the red-hot iron. All these conditions being fulfilled an explosion of the gases may take place.

**P**RESERVING FENCE-POSTS.—On this subject the *Journal of Forestry* has the following: The proper seasoning of timber before being used in any structure is far more important than the season of the year it is felled in, kind of timber used, or preventives employed.

There are paints, washes, and heterogeneous steeps recommended for preserving posts, but each are comparatively costly, and only partially successful. One great objection to the application of solutions externally rests on the fact that the sap being confined accelerates decomposition in the interior. Most foresters must have observed this. What I would recommend with fencing-posts is, the materials, when felled, to be directly sawn into posts and stored under sheds thoroughly ventilated, where they will remain at least a year exposed to "sun and wind." The neck or part between wind and water of each post should be slowly charred over a strong fire,—slowly, because our principle means heating the timber thoroughly to the heart, so as to extract any moisture which may be still lodged at the center, and hardening a crust on the surface of the posts. Afterwards, to prevent the posts absorbing water, they should be well coated with coal tar, having its acid destroyed with fresh quicklime. The tar should be thoroughly boiled to evaporate all watery matter, and applied boiling hot. A large tank, holding the posts set on end, and filled with the scalding tar from a boiler, answers the purpose very well. Of course, the upper half of the posts can be painted when placed *in situ*. I am fully convinced coal tar, properly applied to thoroughly seasoned timber, is far more effectual in preserving posts than creosoting poisoning, kyanising, or all the paraphernalia of iron prongs, sheet-iron wrappers (an American invention), &c. One great recommendation in favor of the above process is that it requires no skilled labor, and the cost is a mere trifle.

**THE CONSUMPTION OF SMOKE.**—An address was delivered by Professor Osborne Reynolds, F.R.S., at the inaugural meeting of the Manchester Scientific and Mechanical Society, the subject being the possibility of reducing the quantity of smoke and pernicious gases poured into the atmosphere. He said the ways in which this could be done might be summed up in three :—1. By the better burning of the coal and the purifying of the products from soot and sulphur; 2. The more economical use of coal, and hence the reduction of the quantity consumed; 3. The somewhat transcendental but much more complete method, if it is possible, of substituting some other power for that now derived from coal. With regard to the coal consumed under boilers, the general conclusion to which research had led was that although it was quite possible to completely consume coal in the furnace, yet to do so economically required constant attention and great care. In looking for further reforms, it was the small engines that were the difficulty, for not only did they fail properly to burn their own coal, but they prevented the adoption of measures which might be satisfactorily carried out where the consumption was large. It seemed, therefore, that the chance of further reducing the impurities turned into the air depended greatly on their ability to do away with small engines. This view raised another question, and a somewhat wide one—could they supplant small engines by power derived

either from large engines or some other source? He did not doubt that if the useful work done by the warehouse and other engines in Manchester were measured it would be found to be less than one-fifth what might well be obtained for the same coal. If, therefore, power in a convenient form could be obtained whenever and wherever required, at a fixed and reasonable charge, and with no other trouble than the throwing into gear of a clutch or the turning a tap, there could be no doubt that not only would it be applied in many instances where the inconvenience of a steam engine prevented its being used, but also it would be so largely used to supplant steam engines which were now kept working with little or nothing to do for the greater part of their time as to effect a considerable saving in the consumption of coal. He examined at length the only four ways in which power could be practically conveyed—namely, rotating shafts, endless belts or ropes, water in pipes, and air in pipes. He considered there was no hope for our ever utilising the natural sources of power, such as tidal rivers, for mechanical purposes, unless they conducted them on the banks of those rivers. But as regarded the substitution of a general source of power for the small steam engines now in use in our towns, the case appeared more hopeful; and, what was more, this had already been done in some instances. With the ability to have either water or air at the most convenient pressure and at a reasonable cost, he thought but few users of power on any but the largest scale would care for the trouble, danger, dirt, and expense of having steam engines of their own; and if this were so, there would then be a chance of reducing the impurities in the air.

**IRRIGATION IN INDIA.**—We are not a little pleased to find so eminent an authority as Sir Arthur Cotton holding opinions identical with those to which we have already given expression, concerning the relative value of irrigation and railways in Hindustan. Sir Arthur delivered an address to the Liverpool Chamber of Commerce on Wednesday, in which he said that his views were diametrically opposed in every important particular to those held by the officials of the India Office, both past and present. The Duke of Argyll, speaking on the subject not long ago, alluded to his—Sir Arthur's—opinions as mere visionary ideas, but he thought that was hardly the way to dismiss the opinions of one who, like himself, had had over forty years' experience as a civil engineer in India, and who had been engaged in the construction of two of the most extensive and successful irrigation works in that country. Sir Arthur proceeded to give the results of the irrigation works carried out up to the present time. The district of Tanjore, for instance, since the water had been introduced, had gone on in one uninterrupted chain of improvement. The revenue had increased from £430,000 a year to £750,000; the population was nearly doubled; and it was now, with only one exception, the most flourishing district in the whole of India. That exception was the district of Godavery. In 1846 this

district was in such a miserable state that the Government feared open rebellion, and he was sent down there to report, and to project works for the improvement of the land. They were five or six years in constructing the head works and main channels of the canal, and the continuation of the works had occupied from that time to the present. The Godavery district had increased two and a-half fold, and now was the most thriving district in India. In fact, the only three districts in the Madras Presidency where irrigation works had been adopted were now yielding a net profit to the Government of 15, 21, and 87 per cent. respectively. But in addition to the value of canals for irrigating purposes, they were available for transit; indeed, he had come to the conclusion of late years that cheap internal transit was even of more importance to the people than was irrigation, as by this means the whole interior of the country would be developed, and as far as the north-west provinces were concerned, all that fertile grain-producing country would be afforded cheap and easy communication with Calcutta, and so be enabled to supply the English market. At present this was impossible, owing to the high railway charges. The irrigation works so far carried out had cost on an average about £2 an acre, and the return on this in extra crops had been quite 100 per cent. Contrasting canal with railway works, Sir Arthur said that in Madras the Government had spent 14 millions on railways, and the return was about 2½ per cent.; but had this prevented the famine? In the same presidency there were three districts returning from 15 to 40 per cent. on the outlay for irrigation works, the land was overflowing with plenty, the people were prosperous, and immense quantities of grain were sent to the relief of the famine-stricken districts. In conclusion, he urged that if the Government would only develop the resources and revenues of India by means of a complete system of irrigation—for that he held to be the only really practical mode of improving the country—they would benefit both this country and India in many ways.—*Engineer.*

#### THE LONGEST TRUSS SPAN IN THE WORLD.—

The Philadelphia *North American* says another solid achievement in bridge building and engineering has been made by the Keystone Bridge Company, in the successful completion of the longest span of truss bridge in the world. The bridge was built for the Cincinnati Southern Railway over the Ohio River. The first long span of truss bridge attempted in this country was the Ohio River bridge, at Steubenville, with a channel span of 320 feet. It was designed by J. H. Linville, and manufactured and erected under his supervision. Then followed spans of 350 feet at Parkersburg and Blair, of the Linville truss; then the 420-foot span at Cincinnati, and the great steel arch bridge at St. Louis with several spans, one of 515 feet, two of 500 feet, and others shorter. These were all erected by the Keystone Company. The new structure was tested on the 8th inst. Five of the spans comprising the bridge proper over the Ohio were built by the Keystone Company and five others on the

Ohio side, over the streets and houses, by the Baltimore Bridge Company. The former was also awarded the contract for the eleventh span and the bridge over Eighth street. The structure as it stands cost nearly \$700,000. Span No. 3 over the main current is 519 feet long—the longest truss span in the world. The bridge is built entirely of iron, except the cross-ties for the track and the guard rails. All the spans rest upon solid masonry piers, except the north end approach, which has iron piers with masonry bases. All the river piers are upon a rock foundation. Those upon the shore are upon a foundation of piles. The two piers supporting the long span are 110 and 119 feet high and 11 by 26 feet under the coping. The top of the rail is 105½ feet above extreme low water mark, and 43 feet above high water mark of 1832. The testing was performed with locomotives.

#### PROGRESS OF THE ST. GOTHARD TUNNEL.—

The advancement made at the St. Gothard Tunnel during the last week in October, was 33 m. at the Göschenen, and 17.9 at the Airold—*a progress of 7.2 m. per day.* During all last week the work at the Airold was interrupted by a terrible conflagration which almost completely destroyed the village.

The Federal council has addressed a circular to the governments of the cantons interested in the construction of the St. Gothard Railroad, calling their attention to the sensible progress made in the construction of the tunnel during the fifth year of the work, as compared with the preceding years. The circular says that, excepting unforeseen obstacles, the tunnel will be completed in three years.

MR. W. HIGGINBOTTOM, the Mayor of Derby, wishes to make known the fact that the nucleus of a committee is forming there for the purpose of enabling the admirers of Mr. James Allport, the general manager of the Midland Railway, to combine in presenting him with a testimonial, in recognition of his public-spirited policy. Mr. Higginbottom suggests that the Lord Mayor of London should be prevailed upon to lend his assistance to the furtherance of this object, in which case his lordship's example would doubtless be followed by provincial mayors throughout the kingdom.

MR. THOMAS COLSON, C.E., who was specially sent out by Government to take charge of and complete the waterworks at Singapore, has returned to London, having accomplished his mission. For twenty years past efforts have from time to time been made to supply Singapore with water, but, owing to various causes, they have been unsuccessful. All difficulties, however, have been surmounted under the management of Mr. Colson, and that gentleman has been awarded much praise by the Singapore press for the ingenuity and skill displayed by him in his labors.

Two patents for inventions by Mr. Wilde for the working of electric telegraphs have been extended. The patent granted in 1863 is extended for seven years, and a second patent, obtained in 1865, is prolonged for five years, so that both will expire together in the year 1884.

# VAN NOSTRAND'S

## ECLECTIC

# ENGINEERING MAGAZINE.

NO. CX.—FEBRUARY, 1878.—VOL. XVIII.

### A NEW GENERAL METHOD IN GRAPHICAL STATICS.

BY HENRY T. EDDY, C. E., Ph. D., University of Cincinnati.

Written for VAN NOSTRAND'S MAGAZINE.

#### II.

##### WHEEL WITH TENSION-ROD SPOKES.

A very interesting example is found in the wheel represented in Fig. 4, in which the spokes are tension rods, and the rim is under compression. Let the greatest weight which the wheel ever sustains be applied at the hub of the wheel

on the left, and let this weight be represented by the force  $aa'$  on the right, which is also equal to the reaction of the point of support upon which the wheel stands; hence  $aa'$  represents the force acting between two joints of this frame. The same effect would be caused

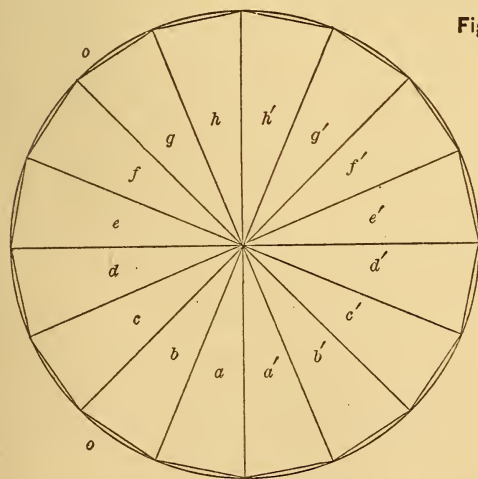
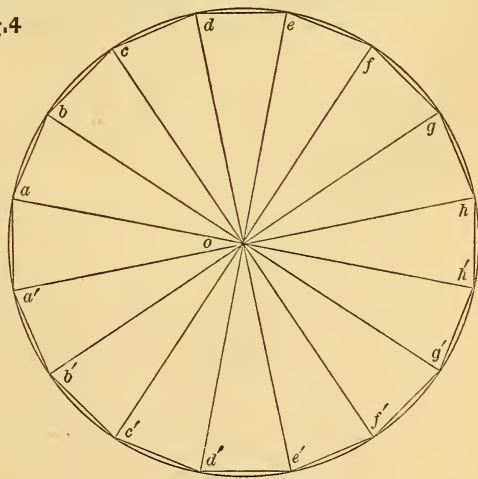


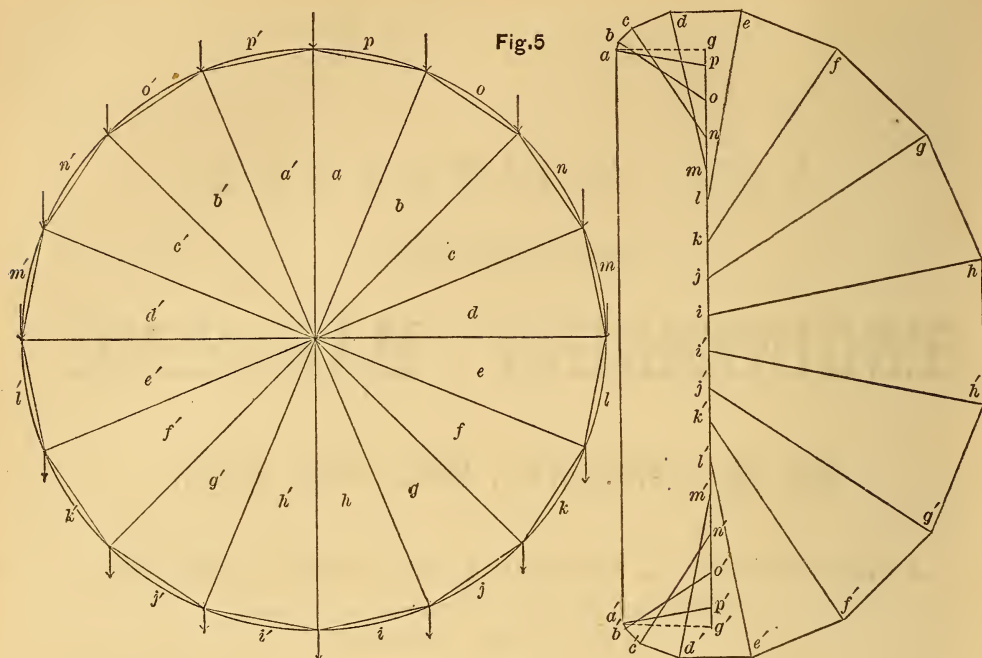
Fig.4



upon the other members of the frame by "keying" the rod  $aa'$  sufficiently to cause this force to act between the hub and the lowest joint.

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It should be noticed in passing, that the weights of the parts of the wheel itself are not here considered; their effect will be considered in Fig. 5. Also, the



construction is based upon the supposition that there is a flexible joint at the extremity of each spoke. This is not an incorrect supposition when the flexibility of the rim is considerable compared with the extensibility of the spokes, a condition which is fulfilled in practice.

A similar statement holds in the case of the roof truss with continuous rafters, or a bridge truss with a continuous upper chord. The flexibility of the rafters or the upper chord is sufficiently great in comparison with the extensibility of the bracing, to render the stresses practically the same as if pin joints existed at the extremities of the braces.

Furthermore, the extremities of the spokes are supposed to be joined by straight pieces, since the forces between the joints of the rim act in those directions. Such forces will cause small bending moments in the arcs of the rim joining the extremities of the spokes. Each arc of the rim is an arch subjected to a force along its chord or span, and it can be treated by the method applicable to arches. This discussion is unimportant in the present case and will be omitted.

Upon completing the force polygon in the manner previously described, it is found that the stress on every spoke is

the same in amount, and is represented by a side of the regular polygon  $abcd$ , etc. upon the left, while the compression of the pieces of the rim are represented by the radii  $oa$ ,  $ob$ , etc.

As previously explained these diagrams are mutually reciprocal, and it happens in this case that they are also similar figures.

We then conclude that in designing such a wheel each spoke ought to be proportioned to sustain the total load, and that the maker should key the spokes until each spoke sustains a stress at least equal to that load. Then in no position of the wheel can any spoke become loose. The load here spoken of, includes, of course, the effect of the most severe blow to which the wheel may be subjected while in motion.

#### WATER WHEEL WITH TENSION-ROD SPOKES.

The effect of a load distributed uniformly around the circumference of such a wheel as that just treated is represented in Fig. 5. Should it be desirable to compute the effect of both sets of forces upon the same wheel, it will be sufficient to take the sum of the separate effects upon each piece for the total effect upon that piece, though it is perfectly possible to construct both at once.

We shall suppose a uniform distribution of the loading along the circumference in the case of the Water Wheel, because in wheels of this kind such is practically the case so far as the spokes are concerned, since the power is transmitted, not through them to the axis, but, instead, to a cog wheel situated near the center of gravity of the "water arc." This arrangement so diminishes the necessary weight of the wheel, and the consequent friction of the gudgeons, as to render its adoption very desirable.

The discussion of the stresses appears however, to have been heretofore erroneously made.\*

Let the weight  $pp'$ , at the highest joint of the wheel, be sustained by the rim alone, since the spoke  $aa'$  cannot assist in sustaining  $pp'$ , as  $aa'$  is suited to resist tension only. Conceive, for the moment, that two equal and opposite horizontal forces are introduced at the highest joint such as the two parts of the rim exert against each other, then  $\frac{1}{2}pp' = pq = p'q'$  being sustained by each of the pieces  $ap$ ,  $a'p'$  respectively we have  $apq$  and  $a'p'q'$  as the triangles which together represent the forces at the highest joint. The force  $aa'$  on the right is the upward force at the axis, equal and opposed to the resultant of the total load upon the wheel, and the apparent peculiarity of the diagram is due to this;—the direction of the reaction or sustaining force of the axis passes through the highest joint of the wheel and yet it is not a force acting between those joints and could not be replaced by keying the tie connecting those joints. In other particulars the force diagram is constructed as previously described and is sufficiently explained by the lettering. Should the spoke  $aa'$  have an initial tension greater than  $pp'$ , then there is a residual tension due to the difference of those quantities whose effect must be found as in Fig. 4.

Should the wheel revolve with so great a velocity that the centrifugal force must be considered, its effect will be to increase the tension on each of the spokes by the same amount,—the amount due to the deviating force of the mass supposed to be concentrated at the extremity of each spoke. The compression of the

rim may be decreased by the centrifugal force, but as this is a temporary relief, occurring only during the motion, it does not diminish the maximum compression to which the rim will be subjected.

We conclude then, that every spoke must be proportioned to endure a tension as great as  $hh'$  from the loading alone; and that if other forces, due to centrifugal force or to keying, are to act they must be provided for in addition. Furthermore, we see that the rim must be proportioned to bear a compression as great as  $hi$ , due to the loading alone, and that the centrifugal force will not increase this, but any keying of the spokes beyond that sufficient to produce an initial tension on each spoke as great as  $pp'$  must be provided for in addition.

The diagram could have been constructed with the same facility in case the applied weights had been supposed unequal.

It can be readily shown that the differential equation of the curve circumscribing the polygon  $abcd$ , etc. of Fig. 5. is

$$y + x \frac{dx}{dy} + c \tan^{-1} \left( \frac{dx}{dy} \right) = 0$$

which equation is not readily integrable. When, however, the number of spokes is indefinitely increased, it appears from simple geometrical considerations that this curve becomes a cycloid having its cusps at  $q$  and  $q'$ .

#### ASSUMED FRAMING.

Thus far, we have treated the effect of known external forces upon a given form of framing, and it is evident from the previous discussions and the illustrative examples that any such problem, which is of a determinate nature, can be readily solved by this method. But in case the problem under discussion has reference to the relations of forces among themselves, it is necessary to assume that the forces are applied to a frame or other body, in order to obtain the required relationship. Certain general forms of assumed framing have properties which are of material assistance in treating such problems, and this is true to such an extent that even though the form of framing to which the forces are applied is given, it is still advantageous to assume, for the time being, one of the

\* "A Manual of the Steam Engine, etc.," by W. J. M. Rankine. Page 182, 7th Ed.

forms having properties not found in ordinary framing. The special framing which has been heretofore assumed for such purposes is the Equilibrium Polygon, whose various properties will be treated in order. We now propose another form of framing, which we have ventured to call the Frame Pencil, with equally advantageous properties which will also be treated in due order.

It may be mentioned here, that the particular case of parallel forces is that most frequently met with in practice. In case of parallel forces the properties of the equilibrium polygon and frame pencil are more numerous and important than those belonging to the general case alone. We shall first treat the general case, and afterwards derive the additional properties belonging to parallel forces.

## EQUILIBRIUM POLYGON.

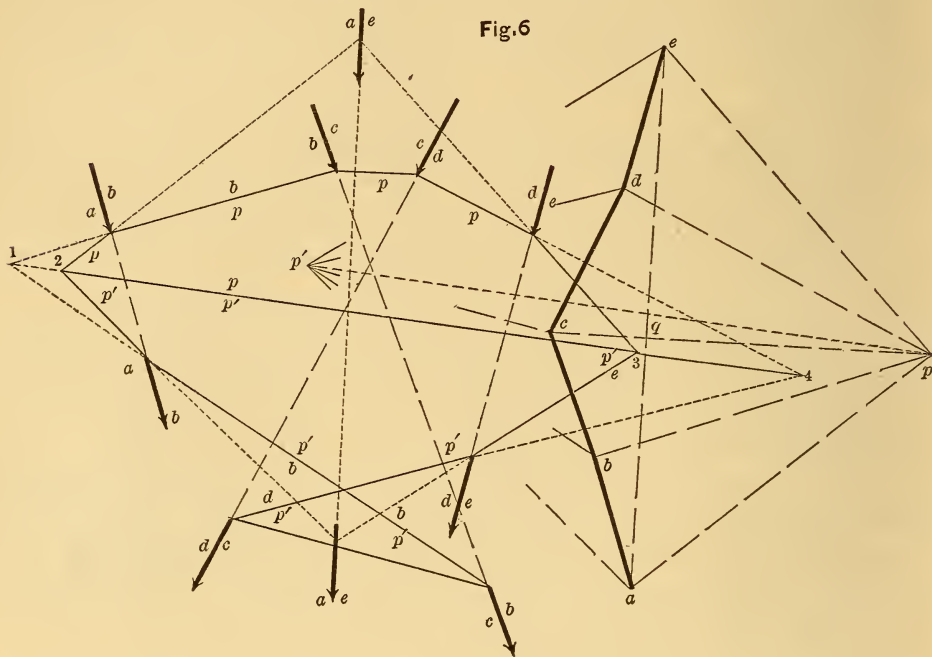


Fig. 6

## RECIPROCAL FIGURES.

Direction and Position.	{	Force Diagram,	$abcde,$	Force Polygon.	} Direction and Magnitude.
		Equilibrium Polygon,	$ap, bp, cp, dp, ep,$	Force Pencil.	
		Equilibrium Polygon,	$ap', bp', cp', dp', ep',$	Force Pencil.	
		Closing Line,	$23 \parallel pq,$	Closing Ray.	
		Resultant Force,	$ae,$	Resultant Force.	

## THE EQUILIBRIUM POLYGON FOR ANY FORCES IN ONE PLANE.

Let  $ab, bc, cd, de$  Fig. 6 be the diagram of any forces lying in the plane of the paper, and  $abcde$  their force polygon, then, as previously shown,  $ae$  the closing side of the polygon of the applied forces represents the resultant of the given forces in amount and direction. Assume any point  $p$  as a pole, and draw the force pencil  $p-abcde$ . The object in view in so doing, is to use this force pencil and polygon of the applied forces

together in order to determine a figure of which it is the reciprocal.

From any convenient point as 2 draw the side  $ap$  parallel to the ray  $ap$  until it intersects the line of action of the force  $ab$ , and from that intersection draw the side  $bp$  parallel to the ray  $bp$ , etc., etc.; then the polygon  $p$  will have its sides parallel respectively to the rays of the pencil  $p$ .

The polygon  $p$  and the given forces  $ab, bc$ , etc., then form a force and frame diagram to which the pencil  $p-abcde$  is

reciprocal, and of which it is the force diagram. It is seen that no internal bracing is needed in the polygon  $p$ , and hence it is called an equilibrium (frame) polygon: it is the form which a funicular polygon, catenary, or equilibrated arch, would assume if occupying this position and acted upon by the given forces.

As represented in Fig. 6 the sides of the polygon  $p$  are all in compression so that  $p$  represents an ideal arch. If the line 23 be drawn cutting the sides  $ap$ ,  $ep$  so that it be considered to be the span of the arch having the points of support 2 and 3, then this arch exerts a thrust in the direction 23 which may be borne either by a tie 23 or by fixed abutments 2 and 3: the force in either case is the same and is represented by  $pq \parallel 23$ . It is usual to call 23 a closing line of the polygon  $p$ . The point  $q$  divides the resultant  $ae$  into two parts such that  $qapq$  and  $epqe$  are triangles whose sides represent forces in equilibrium, i.e., the forces at the points 2 and 3; hence,  $qa$  and  $eq$  are the parts of the total resultant which would be applied at 2 and 3 respectively.

This method is frequently employed to find the forces acting at the abutments of a bridge or roof truss such as that in Fig. 2. But it appears that it has often been erroneously employed. It must be first ascertained whether the reaction at the abutments is really in the direction  $ae$  for the forces considered. It may often happen far otherwise. If the surfaces upon which the truss rests without friction are perpendicular to  $ae$ , then this assumption is probably correct; as, for instance, when one end is mounted on rollers devoid of friction, running on a plate perpendicular to  $ae$ . But in cases of wind pressure against a roof truss the assumption is believed to be in ordinary cases quite incorrect. Indeed, the friction of the rollers at end of a bridge has been thought to cause a material deviation from the determination founded on this assumption. It is to be noticed that any point whatever on  $pq$  (or  $pq$  prolonged) might be joined to  $a$  and  $e$  for the purpose of finding the reactions of the abutments. Call such a point  $x$  (not drawn), then  $ax$  and  $ex$  might be taken as two forces which are exerted at 2 and 3 by the given system. It appears necessary to call attention to this

point, as the fallacious determination of the reactions is involved in a recently published article upon this subject.\* We shall return to the subject again while treating parallel forces and shall extend the method given in connection with Fig. 2 to certain definite assumptions, such as will determine the maximum stresses which the forces can produce.

Prolong the two sides  $ap$  and  $ep$  of the polygon  $p$  until they meet. It is evident that if a force equal to the resultant  $ae$  be applied at this intersection of  $ap$  and  $ep$  prolonged, then the triangles  $apq$  and  $epq$  will represent the stresses produced at 2 and 3 by the resultant. But as these are the stresses actually produced by the forces, and as the resultant should cause the same effects at 2 and 3 as the forces, it follows that the intersection of  $ap$  and  $ep$  must be a point of the resultant  $ae$ ; and if, through this intersection, a line be drawn parallel to the resultant  $ae$ , it will be a diagram of the resultant, showing it in its true position and direction.

This is in reality a geometric relationship and can be proved from geometric considerations alone. It is sufficient for our purposes, however, to have established its truth from the above mentioned static considerations which may be regarded as mechanical proof of the geometric proposition.

The pole  $p$  was taken at random: let any other point  $p'$  be taken as a pole. To avoid multiplying lines  $p'$  has been taken upon  $pq$ . Now draw the force pencil  $p'-abcde$  and the corresponding equilibrium polygon for the same forces  $ab$ ,  $bc$ , etc. This equilibrium polygon has all its pieces in tension except  $p'c$ . It is to be noticed that the forces are employed in the same order as in the previous construction, because that is the order in the polygon of the applied forces: but the order of the forces in the polygon of the applied forces is, at the commencement, a matter of indifference, for the construction did not depend upon any particular succession of the forces.

As previously shown, the intersection of  $ap'$  with  $ep'$  is a point of the resultant, and the line joining this intersection

\* See paper No. 71 of the Civil Engineers' Club of the Northwest. Applications of the Equilibrium Polygon to determine the Reactions at the Supports of Roof Trusses, By James R. Willett, Architect. Chicago.

with the corresponding intersection above is parallel to  $ae$ .

Again, prolong the corresponding sides of the two equilibrium polygons until they intersect at 1234, these points fall upon one line parallel to  $pp'$ . For, suppose the forces which are applied to the lower polygon  $p'$  to be reversed in direction, then the system applied to the polygons  $p$  and  $p'$  must together be in equilibrium; and the only bracing needed is a piece  $23 \parallel pp'$ , since the upper forces produce a tension  $pq$  along it, and the lower forces a tension  $qp'$ , while the parts  $aq$  and  $qe$  of the resultant which are applied at 2 and 3 are in equilibrium. The same result can be shown to hold for each of the forces separately; e.g. the opposite forces  $ab$  may be considered as if applied at opposite joints of a quadrilateral whose

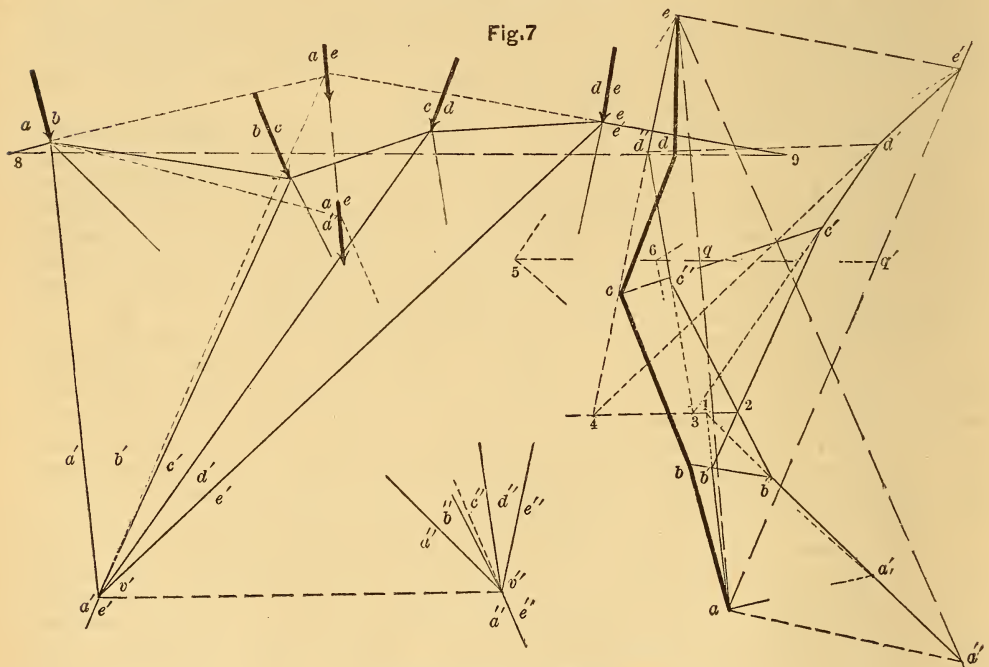
remaining joints are 1 and 2: the force polygon corresponding to this quadrilateral is  $apbp'$ , hence  $12 \parallel pp'$ . Hence 1234 is a straight line. The intersection of  $pc$  and  $p'e$  does not fall within the limits of the figure.

It is to be noticed that the proposition just proved respecting the collinearity of the intersections of the corresponding sides of these equilibrium polygons is one of a geometric nature and is susceptible of a purely geometric proof.

#### THE FRAME PENCIL FOR ANY FORCES IN ONE PLANE.

Let  $ab, bc, cd, de$  in Fig. 7 represent a system of forces, of which  $abcde$  is the force polygon. Choose any single point upon the line of action of each of these

#### FRAME PENCILS.



#### RECIPROCAL FIGURES.

Direction and Position.	Force Diagram,	$abcde$ ,	Force Polygon.	Direction and Magnitude.
	Frame Pencil,	$a'b'c'd'e'$ ,	Equilibrating Polygon.	
	Frame Pencil,	$a''b''c''d''e''$ ,	Equilibrating Polygon.	
	Frame Polygon,	$bb', cc', dd', ee'$ ,	Force Lines.	
	Resultant Force,	$ae$ ,	Resultant Force.	
	Resultant Ray,	$a'e'$ ,	Resultant Side.	

forces, and join these points to any assumed vertex  $v'$  by the rays of the frame pencil  $a'b'c'd'e'$ . Also join the success-

ive points chosen by the lines  $bb', cc', dd'$  which form sides of what we shall call the frame polygon. Now consider the

given forces to be borne by the frame pencil and frame polygon as a system of bracing, which system exerts a force at the vertex  $v'$  in some direction not yet known, and also exerts a force along some assumed piece  $ee'$ , which may be regarded as forming a part of the frame polygon. The stresses upon the rays of the frame pencil will be represented by the sides of  $ab'c'd'e'$  which we shall call the equilibrating (force) polygon; while the stresses in the frame polygon are given by the force lines  $bb'$ ,  $cc'$ , etc. If a resultant ray  $a'e'$  be drawn from  $v'$  parallel to the resultant side  $ae'$  of the equilibrating polygon it will intersect  $ee'$  at a point of the resultant of the system of forces; for that is a point at which if the resultant be applied it will cause the same stresses along the pieces  $a'e'$  and  $ee'$  which support it as do the forces themselves.

If the point  $e'$  in the force polygon be moved along  $e'd'$ , the locus of the intersection of the corresponding positions of the resultant ray  $a'e'$  and the last side  $ee'$  will be the resultant  $ae$ . It would have been unnecessary to commence the equilibrating polygon at  $a$  had the direction of  $aa'$  been known. Having obtained the direction of  $aa'$  as shown at 8, the equilibrating polygon could be drawn by commencing at any point of  $aa_1 \parallel aa'$ .

In cases like that in the Fig., where there is no reason for choosing the points which determine the sides of the frame polygon otherwise, it is simpler to make the frame polygon a straight line, which may in that case be called the frame line. Then the force lines are parallel to each other and to  $aa'$  also. This is a practical simplification of the general case of much convenience.

It should be noticed here that the equilibrium polygon, as well as the straight line, is one case of the frame polygon. The interesting geometric relationships to be found by constructing the frame and equilibrium polygons as coincident must be here omitted.

Suppose that it is desired to find the point  $q$  which divides the resultant into two parts, which would be applied in the direction of the resultant at two such points as 8 and 9: draw  $a6 \parallel v'8$  and  $e'6 \parallel v'9$  and then through 6 draw  $qq' \parallel 89$ . This may be regarded as the

same geometric proposition, which was proved when it was shown that the locus of the intersection of the two outside lines of the equilibrium polygons (reciprocal to a given force pencil) is the resultant, and is parallel to the closing side of the polygon of the applied forces. The proposition now is, that the locus of the intersection of the two outside lines of the equilibrating polygon (reciprocal to a given frame pencil) is the resolving line, and is parallel to the abutment line: for these two statements are geometrically equivalent.

Assume a different vertex  $v''$ , and draw the frame pencil and its corresponding equilibrating polygon  $a''b''c''d''e''$ . If  $a_1 5$  and  $e 5$  be drawn parallel to  $v'' 8$  and  $v'' 9$  respectively their intersection is upon  $qq'$  as before proven.

Again, the corresponding sides of these two equilibrating polygons intersect at 1 2 3 4 upon a line parallel to  $v'v''$ , for this is the same geometric proposition respecting two vertices and their equilibrating polygons which was previously proved respecting two poles and their equilibrium polygons.

It would be interesting to trace the geometric relations involved in different but related frame polygons, as for example, those whose corresponding sides intersect upon the same straight line, but as our present object is to set forth the essentials of the method, a consideration of these matters is omitted. Enough has been proven, however, to show that we have in the frame pencil an independent method equally general and fruitful with that of the equilibrium polygon.

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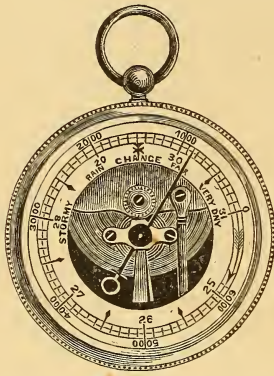
IRON articles to be bronzed are, according to a process by M. P. Hess, heated in the air after being coated with linseed oil. Objects which cannot be exposed to high temperature may be steeped in a slightly acid solution of ferric chloride, plunged in hot water, and when dry rubbed with linseed oil or with wax. To preserve iron from rust the author recommends sulphide of copper. He steeps the iron for a few minutes in a solution of sulphate of copper, and then transfers it into a solution of hyposulphite of soda acidulated with hydrochloric acid. The result is a blue-black coating, not affected by air or water.

## THE ANEROID BAROMETER, ITS CONSTRUCTION AND USE.

Compiled for VAN NOSTRAND'S MAGAZINE.

## I.

Two forms of Barometer are used by physicists for measuring the pressure of the atmosphere: the Mercurial and the Aneroid. The first was invented by Toricelli in 1643. It is too well known to require description; it will be sufficient to say that it measures the varying pressure of the air by the varying length of a column of mercury which balances the pressure.



The Aneroid was invented about the beginning of this century, but was not brought to a serviceable form until within the last thirty years when M. Vidi of Paris succeeded in conquering the difficulties of construction and produced an instrument which has of late been steadily gaining in the estimation of scientists. Meteorologists, geographical explorers, and civil engineers alike concur in praising the usefulness and accuracy of the more portable forms of this instrument. It is, however, only the best and latest improved construction that will justify such confidence.

Captain R. H. Fawcett, who has had much practice in contouring, writes in the *United Service Journal*, vol. xvi.: "The value of the aneroid as a handy and portable instrument for rapidly obtaining relative heights in surveys, has, I think, been under-rated. It is of great value, especially in cases of military surveying, where time is frequently priceless. The points chiefly valuable in an aneroid are its portability, as in the

pocket it takes up no more room than a watch, and the observations and calculations can be done so quickly that a staff officer riding from one hill to another can readily obtain their relative heights. In a survey readings may be noted down in a pocket-book, or even on the margin of the sketch, and calculated out on return at leisure. When there is plenty of time and the ground is practicable, leveling or contouring would certainly be adopted in preference; but even then the occasional consultation of the aneroid might be an advantageous check to error. But if pressed for time, or contouring be impracticable or extremely difficult, the aneroid gives heights with sufficient accuracy for ordinary military operations, and is far more accurate than the eye; moreover, the reading may be taken in equal or less time than it would require in most cases to make a good judgment of height. . . . Though it cannot show the height with the accuracy of leveling or contouring, yet its indications may be generally relied on to ten feet or twenty feet. . . . It is of course in abrupt, hilly and almost mountainous countries that the aneroid is most useful. For heights of fifty feet or sixty feet above the plain varying slightly in their relative heights, the reading of the pocket aneroid might be difficult, and the slightest error important. . . . It almost invariably happens that such small heights can be contoured or leveled quickly, but the case is different with hills of 300 feet or 400 feet above points in the survey. The contouring of these would take up much time, and the advantage of the aneroid, as far as this reason goes, increases with the height."

Thus the traveler amid snowy peaks and glaciers, on plateau or prairie, can tell within a hundred feet his elevation above the sea; a triumph of science no less wonderful than that by which he ascertains his latitude by means of the sextant. With due precautions the aneroid will measure heights with surprising accuracy, as has been repeatedly proved

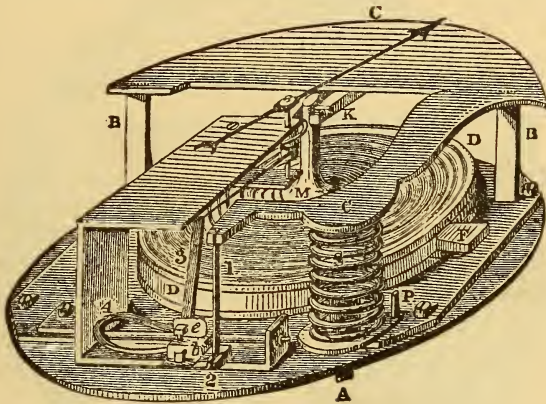
by trigonometrical measurements. For rough practical purposes it is all that can be desired for contouring mountains and hilly districts, with rapidity. It is unnecessary to dwell upon the value of these results to the sciences of geography and topography. Sir J. Herschel in his treatise on "Physical Geography" remarks on this subject: "Barometrical observations both stationary and itinerant, assisted of late by that very useful and portable form of the barometer called the aneroid, which can be read off in a carriage or on horseback, have been now so far extended over the whole accessible surface of the globe, as to afford

ground for a reasonable conclusion respecting the average elevation of the surface of the land above the sea level, and a very accurate one as to the heights of mountain chains and summits.

The aneroid depends for its action upon the changes in form of a thin metallic box partially exhausted of air, as the pressure of the atmosphere varies. In Vidi aneroid the metallic box was cylindrical in shape with thin corrugated ends. In some later forms the box is crescent or  $\cap$  shaped.

The following diagrams exhibit the mechanism of the instrument:

The vacuum chamber, A (Fig. 1) is



flat and circular, having its top and bottom corrugated in concentric circles, to render them more elastic. In the best constructed aneroids the top of the chamber is, in a certain degree, held up in opposition to the pressure of the atmosphere by the elasticity of a folded lamina of spring steel, B, the pull of which on the chamber is regulated by the pressure of a screw beneath the arm, C; by means of this screw, which is reached from an aperture in the bottom of the case, the index error may be corrected whenever such is found to exist; and it may be here remarked that small index errors will occasionally arise, until by a little time and use, the numerous moveable parts of the instrument have assumed their permanent bearings; when, however, it is duly seasoned, it may, if originally well constructed, be carried about with ordinary care in traveling, without undergoing any sensible change.

The folded spring, B, is firmly con-

nected with a stud on the center of the vacuum chamber (which has been carefully exhausted by an air-pump, and the aperture soldered up), and rises and falls with it in obedience to atmospheric pressure. An arm, D, is attached to the spring, at the further extremity of which the actual movements of B are considerably amplified.

The end of D is connected by a link with a short arm proceeding from a transverse bar, F, which is movable on its axis. A long arm proceeding upwards from F, is attached by its extremity, G, to the end of a steel chain (similar to the fusee chain of an English watch), which is wound round a small pulley on the axis of the hand or index. A spiral balance-spring, attached by one end to the pulley, and by the other to the framework, opposes the pull on the chain at G, and causes the index to retreat when the chain is relaxed.

Fig. 2 exhibits in perspective a form slightly different; the spiral-spring S

performing the same function as the laminated spring B in Fig 1.

The errors to which the aneroid is subject arise from the property of the metals used in construction to vary their dimensions with every change of temperature, and thus introduce motions into the mechanism which are independent of atmospheric pressure.

The mercurial barometer is subject to fluctuations due to temperature, but these are easily allowed for as the possible changes are few and simple; but in the aneroid, where metals whose elasticity is not constant are under ten-

sion, it is readily comprehended that skillful adjustment is needed to secure *compensation* as it is termed. This is partly effected by the residue of air in the sealed box, but a further adjustment of a compound spring is also required. The aneroid requires occasional comparison with a standard mercurial barometer and a correction when it varies, to make it agree.

When the barometer is employed for the purposes of meteorology only, the following facts are taken into consideration. We quote from Buchan's "Handy Book of Meteorology":

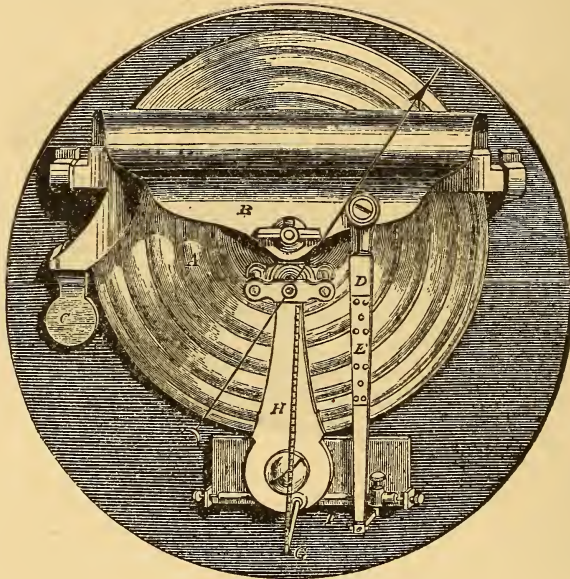


FIG. 2.

*Variations of the Barometer.*—The variations observed in the pressure of the air may be divided into two classes—viz., periodical and irregular; the periodical variations recurring at regular intervals, whilst the irregular variations observe no stated times. The most marked of the periodical variations is the *daily variation*, the regularity of which in the tropics is so great that, according to Humboldt, the hour may be ascertained from the height of the barometer without an error of more than 15 or 17 minutes on the average. This horary oscillation of the barometer is masked in Great Britain by the frequent fluctuations to which the atmosphere is subjected in these regions. It is, however, detected by taking the mean of a

series of hourly observations conducted for some time. The results show two maxima occurring from 9 to 11 A.M. and from 9 to 11 P.M., and two minima occurring from 3 to 5 A.M. and from 3 to 5 P.M. (See Table on following page.)

The maxima occur when the temperature is about the mean of the day, and the minima when it is at the highest and lowest respectively.

This daily fluctuation of the barometer is caused by the changes which take place from hour to hour of the day in the temperature, and by the varying quantity of vapor in the atmosphere.

The surface of the globe is always divided into a day and night hemisphere, separated by a great circle which revolves with the sun from east to west in twenty-

TABLE SHOWING THE DAILY VARIATIONS AND RANGE OF THE BAROMETER IN DIFFERENT LATITUDES.

	LAT.	A.M.		P.M.		RANGE.
		MIN.	MAX.	MIN.	MAX.	
		Inches.	Inches.	Inches.	Inches.	Inches.
Atlantic Ocean.....	0.0	— .056	+ .069	— .045	+ .045	.125
Pacific Ocean.....	0.0	— .032	+ .040	— .045	+ .028	.085
Sierra Leone.....	8.28 N.	— .022	+ .032	— .038	+ .031	.070
Lima.....	12.3 S.	— .071	+ .065	— .067	+ .050	.126
Calcutta.....	22.36 N.	— .017	+ .052	— .038	+ .018	.090
Pekin.....	39.53 N.	— .038	+ .047	— .052	+ .014	.099
Great St. Bernard.....	45.51 N.	— .010	+ .005	— .003	+ .012	.022
Plymouth (England)...	50.21 N.	— .007	+ .006	— .010	+ .010	.020
St. Petersburg.....	59.58 N.	— .003	+ .008	— .004	+ .002	.012

four hours. These two hemispheres are thus in direct contrast to each other in respect of heat and evaporation. The hemisphere exposed to the sun is warm, and that turned in the other direction is cold. Owing to the short time in which each revolution takes place, the time of greatest heat is not at noon, when the sun is in the meridian, but about two or three hours thereafter; similarly, the period of greatest cold occurs about four in the morning. As the hemisphere under the sun's rays becomes heated, the air, expanding upwards and outwards, flows over upon the other hemisphere where the air is colder and denser. There thus revolves round the globe from day to day a wave of heat, from the crest of which air constantly tends to flow towards the meridian of greatest cold on the opposite side of the globe.

The barometer is influenced to a large extent by the elastic force of the vapor of water invisibly suspended in the atmosphere, in the same way as it is influenced by the dry air (oxygen and hydrogen). But the vapor of water also exerts a pressure on the barometer in another way. Vapor tends to diffuse itself equally through the air; but as the particles of air offer an obstruction to the watery particles, about 9 or 10 A.M., when evaporation is most rapid, the vapor is accumulated or pent up in the lower stratum of the atmosphere, and being impeded in its ascent its elastic force is increased by the reaction, and the barometer consequently rises. When the air falls below the temperature of the dew-point, part of its moisture is de-

posited in dew, and since some time must elapse before the vapor of the upper strata can diffuse itself downwards to supply the deficiency, the barometer falls—most markedly at 10 P.M., when the deposition of dew is greatest.

Hence, as regards temperature, the barometer is subject to a maximum and minimum pressure each day,—the maximum occurring at the period of greatest cold, and the minimum at the period of greatest heat. And as regards vapor in the atmosphere, the barometer is subject to two maxima and minima of pressure—the maxima occurring at 10 A.M., when, owing to the rapid evaporation, the accumulation of vapor near the surface is greatest, and about sunset, or just before dew begins to be deposited, when the relative amount of vapor is great; and the minima in the evening, when the deposition of dew is greatest, and before sunrise, when evaporation and the quantity of vapor in the air is least.

Thus the maximum in the forenoon is brought about by the rapid evaporation arising from the dryness of the air and the increasing temperature. But as the vapor becomes more equally diffused, and the air more saturated, evaporation proceeds more languidly; the air becomes also more expanded by the heat, and flows away to meet the diurnal wave of cold advancing from the eastwards. Thus the pressure falls to the afternoon minimum about 4 P.M. From this time the temperature declines, the air approaches more nearly the point of saturation, and the pressure being further

increased by accessions of air from the warm wave, now considerably to the westward, the evening maximum is attained. As the deposition of dew proceeds, the air becomes drier, the elastic pressure of the vapor is greatly diminished, and the pressure falls to a second minimum about 4 A.M.

The amount of these daily variations diminishes from the equator towards either pole, for the obvious reason that they depend, directly, or indirectly, on the heating power of the sun's rays. Thus, while at the equator the daily fluctuation is 0.125 inch, in Great Britain it is only a sixth part of that amount. It is very small in the high latitudes of St. Petersburg and Bossekop; and in still higher latitudes, at that period of the year when there is no alternation of day and night, the diurnal variation probably does not occur. In the dry climate of Barnaul, in Siberia, there is no evening maximum; the lowest minimum occurs as early as midnight, and the only maximum at 9 A.M.

Since the whole column of the atmosphere, from the sea-level upwards, expands during the heat of the day, thus lifting a portion of it above all places at higher levels, it is evident that the afternoon minimum at high stations will be less than at lower stations, especially when the ascent from the one to the other is abrupt. Thus, at Padua, in Italy, the afternoon minimum is 0.014 inch, but at Great St. Bernard it is only 0.003 inch.

*Annual Variation.*—When it is summer in the one hemisphere, it is winter in the other. In the hemisphere where summer prevails, the whole air, being warmer than in the other hemisphere, expands both vertically and laterally. As a consequence of the lateral expansion there follows a transference of part of the air from the warm to the cold hemisphere along the earth's surface; and, as a consequence of the vertical expansion, an overflow in the upper regions of the atmosphere in the same direction. Hence, in so far as the dry air of the atmosphere is concerned, the atmospheric pressure will be least in the summer and greatest in the winter of each hemisphere. But the production of aqueous vapor by evaporation being most active in summer, the pressure on the barometer

will be much increased from this cause. As the aqueous vapor is transferred to the colder hemisphere it will be there condensed into rain, and being thereby withdrawn from the atmosphere, the barometer pressure will be diminished; but the dry air which the vapor brought with it from the warm hemisphere will remain, thus tending to increase the pressure.

In the neighborhood of the equator there is little variation in the mean pressure from month to month. Thus, at Cayenne, the pressure in January is 29.903 inches, and in July 29.957 inches.

At Calcutta, 22° 36' N. lat., the pressure is 29.408 in July, and 30.102 in January, thus showing a difference of 0.694; and at Rio de Janeiro, 22° 57' S. lat., it is 29.744 in January (summer), and 29.978 in July (winter), the difference being 0.234. The large annual variation at Calcutta is caused jointly by the great heat in July, and by the heavy rains which accompany the south-west monsoons at this season; while in January the barometer is high, owing to the north-east monsoons, by which the dry cold dense air of Central Asia is conveyed southward over India.

At places where the amount of vapor in the air varies little from month to month, but the variations of temperature are great, the difference between the summer and winter pressures are very striking. Thus, at Barnaul and Irkutsk, both in Siberia, the pressures in July are respectively 29.243 and 28.267, and in January 29.897 and 28.865, the differences being upwards of six-tenths of an inch. The great heat of Siberia during summer causes the air to expand and flow away in all directions, and the diminished pressure is not compensated for by any material accessions being made to the aqueous vapor of the atmosphere; and, on the other hand, the great cold and little rain in that region during winter causes high pressures to prevail during that season. The same peculiarity is seen, though in a modified degree, at Moscow, St. Petersburg, and Vienna.

At Reykjavik, in Iceland, the pressure in June is 29.717, and in December 29.273; at Sandwich, Orkney, 29.775, and 29.586; and at Sitcha, in

Russian America, 29.975, and 29.664. In all these places the distribution of the pressure is just the reverse of what obtains in Siberia, being least in winter and greatest in summer. The high summer pressures are due to the cool summer temperatures as compared with surrounding countries, thus causing an *inflow from these regions*, and to the large amount of vapor in the atmosphere, thus still further raising the barometric column. On the other hand, the low winter pressures are due to the comparatively high winter temperatures causing an *outflow towards adjoining countries*, and the large winter rainfall, which by setting free great quantities of latent heat, still further augments and accelerates the outflow.

The variations in mean pressure are very slight, and not marked by any very decided regularity in their march through the seasons, at Dublin, Glasgow, London, Paris, and Rome. As compared with Barnaul and Reykjavik their temperature is at no season very different from that of surrounding countries, and the vapor and rainfall are at no time much in excess or defect, but are more equally distributed over the different months of the year.

At the Great St. Bernard, 8174 feet above the sea, the pressure in summer is 22.364 inches, while in winter it is only 22.044. At Padua, there is scarcely any difference in the pressure between summer and winter. The increase in the summer pressure at the Great St. Bernard is no doubt due to the same cause already referred to in art. 65—viz., the expansion of the air upward during the warm summer months, thus raising a larger portion of it above the barometer at the highest station. But at St Fe de Bogota, 8615 feet high, near the equator, and where, consequently, the difference between the temperature in July and January is very small, the difference in the pressures of the same months is also very small, being only 0.035.

*Distribution of Atmospheric Pressure over the globe, as determined by the Annual Means.*—Though much additional observation is required, especially in Africa, Asia, and South America, before the isobarometric lines can be laid down on a map of the world, yet many important conclusions regarding the

mean barometric pressure have been arrived at from the results already obtained. We have seen that the daily and monthly variations of pressure observed at different places are modified by the variations of the temperature of the air, the amount of vapor, and the rainfall. Since these are in their turn greatly modified by the unequal distribution of land and water on the earth's surface, we should expect to find the pressure, and the variations in the pressure, most regular in the southern hemisphere. Accordingly, there is a remarkable regularity observed in the distribution of the pressure from about 40° N. lat. southwards to the Antarctic Ocean, with the exception of the region of the monsoons in Southern Asia.

The mean pressure in the equatorial regions is about 29.90; at 20° N. lat. it rises to 30.00, and at 35° N. lat. to 30.20, from which northwards the pressure is diminished. The same peculiarity is seen south of the equator, but it is not so strongly marked. At 45° S. lat. it falls to 29.90, and from this southwards it continues steadily and rapidly to fall to a mean pressure of 28.91 at 75° S. lat. This extraordinary depression of the barometer in the Antarctic Ocean, being one inch less than at the equator, and 1.326 inches less than at Algiers, is perhaps the most remarkable fact in the meteorology of the globe.

The pressure in the north temperate and frigid zones is in striking contrast to the above. From Athens, in a north-eastern direction, a high isobarometric line traverses Asia, passing in its course Tiflis, Barnaul, Irkutsk, and Yakutsk. To the east of the northern, part of this area of high mean pressure around the peninsula of Kamtschatka, there is a region of low barometer, the mean pressure being only 29.682. There is another remarkable area of low pressure around Iceland, the center being probably in the south-west of the island near Reykjavik, where the mean is 29.578. As observations are more numerous in Europe and North America, the dimensions of this depression may be defined with considerable precision by drawing the isobarometric of 29.90, which is about the mean atmospheric pressure. This line passes through Barrow Straits in North America, thence

south-eastward toward Newfoundland, then eastward through the north of Ireland, the south of Scotland, and the south of Sweden, whence it proceeds in a north-easterly direction to Spitzbergen. The following mean annual pressures will show the nature of the depression:—New York, 30.001; Paris, 29.988; London, 29.956; Glasgow, 29.863; Orkney, 29.781; Bergen, 29.804; Spitzbergen, 29.794; Reykjavik, 29.578; Godthaab in S. Greenland, 29.605; Upernavik in N. Greenland, 29.732; and Melville Island, 29.807. A depression also occurs in India, where the mean is only about 29.850, whereas in the same latitudes elsewhere it is about 30.100.

There are thus four areas of low pressure on the globe, the extent of each being nearly proportioned to the depth of the central depression—viz., Antarctic Ocean, the least pressure being 28.910; Iceland, 29.578; Kamtschatka, 29.682; and India, 29.850; and three areas of high pressure, one lying between latitudes 20° and 40° N., another between 15° and 35° S., and the third in Central Asia, from south-west to north-east. These low mean pressures are by no means constant in all cases during the months of the year. In the Antarctic Ocean they are nearly constant during the months, with perhaps a slight tendency to an increase in winter. In the region of low pressure round Iceland, the pressure is a little less than elsewhere in summer; but in winter, when the rainfall is heaviest, it is very much less, being 0.251 inch less in winter than in summer at Reykjavik, and 0.189 at Sandwich, in Orkney. Similarly at Petropaulovski, in Kamtschatka, the pressure in winter is 0.323 less than in summer. Hence the low mean annual pressures in the North Atlantic and the North Pacific are chiefly brought about by the low pressure during the cold months of the year, and are doubtless caused by the copious rainfall during that season. On the other hand, in Southern Asia, the lowest pressures occur in summer. Thus, at Calcutta it is 29.408 in July, while in January it is 30.102—the average pressure for that degree of north latitude. Hence, in Hindostan, the low mean annual pressure arises from the very low pressure in summer caused by the heavy rains fall-

ing at that season, particularly on the south slope of the Himalayas. Generally the pressure is low wherever a copious rainfall prevails over a considerable portion of the earth's surface, owing to the large quantity of caloric set free as the vapor is condensed into rain.

It is scarcely necessary to point out how important it is to keep in mind these facts of the pressure of the atmosphere, it being evident, for instance, that a pressure of 29.00 in the North Atlantic would portend stormy winds, while the same pressure south of Cape Horn, being the mean pressure there, would indicate settled weather.

The readings of the mercurial barometer are subjected in nice observations to several corrections:

- 1st. To 32° F. allowance being made for expansion of both mercury and scale for all observations above that temperature. A barometric pressure of thirty inches at 32° would be indicated by a height of  $30\frac{1}{10}$  inches at 70°.
- 2d. For decrease of gravitation at stations above the level of the sea, acting on both the mercury and the air.
- 3d. For increase of gravity with increase of latitude.
- 4th. For temperature of air; the density decreasing as temperature rises.
- 5th. For humidity of the air which also influences its density.
- 6th. For capillary attraction of the tube.

The Aneroid requires when properly constructed a less number of corrections.

Many of them are so compensated as to require no correction for temperature of the instrument.

A correction for temperature of the air above or below some conventional standard is the only one usually applied to the best aneroids, and the corrections for decreased force of gravity and for humidity are the only other corrections required for the most refined observations.

#### MEASUREMENT OF ALTITUDES.

It is in the measurement of heights that the aneroid is most highly appreciated. Its portability and the ease and

rapidity with which it affords accurate results, render it one of the most satisfactory of scientific instruments.

The text books in physics present formulas for computing heights from barometric observations, based on physical laws which we will briefly give.

If the density of the air were constant throughout, the measurement of heights would be a problem of the simplest character; for as mercury weighs 10,500 times as much as air at the sea level, the mercurial column would fall one inch for every 10,500 inches of ascent above the sea. But air is compressible, and, in accordance with Boyle's law, its density varies with the pressure to which it is subjected.

Now suppose the atmosphere divided into layers of uniform thickness, but so thin that the density may be considered uniform throughout.

Let  $h$  = the thickness of each layer.

$W$  = weight of a cubic foot of air at pressure  $H$ .

$W_1$  = weight of a cubic foot of air at  $H_1$ .  
 $H_0, H_1, \&c.$  = pressures measured in inches of mercury.

Then the pressure upon the unit of surface of any layer is greater than that upon the surface of next higher layer by the weight of a volume of air whose base is the unit of surface and whose height is the thickness of the layer. If one foot be the unit of surface, then this quantity would be  $hW$ . And to express it by height of mercury column, it is

necessary to multiply by  $\frac{30}{2157}$  which gives  $\frac{hW30}{2157}$

But  $W : W_0 :: H : 30$

$W_0$  being the weight of a cubic foot air at the level of the sea ( $=.0807$  at  $32^\circ F$ ).

We have from the above  $W \times 30 = W_0 \times H$ , and the above expression for diminution may be written  $\frac{hW_0H}{2157}$ .

If  $H_0, H_1, H_2$  represent the pressures at the surfaces of the successive layers, we shall have

$$H_1 = H_0 - \frac{hW_0H_0}{2157} = H_0 \left(1 - \frac{hW_0}{2157}\right)$$

$$H_2 = H_1 - \frac{hW_0H_1}{2157} = H_1 \left(1 - \frac{hW_0}{2157}\right)$$

$$H_3 = H_2 - \left(1 - \frac{hW_0}{2157}\right)$$

$$H_n = H_{n-1} \left(1 - \frac{hW_0}{2157}\right)$$

Multiplying these equations and suppressing common factors, we get

$$H_n = H_0 \left(1 - \frac{hW_0}{2157}\right)^n$$

If  $h$  be taken at one foot then  $n$  would represent the number of feet vertically between two stations at which the barometric pressures are  $H_n$  and  $H_0$  respectively.

By substituting for  $W_0$  its value and taking logarithms we have

$$\log. \frac{H_0}{H_n} = n. \log. \left( \frac{2157}{2156.9193} \right)$$

whence

$$n = 60135.4 \times \log. \frac{H_0}{H_1}$$

For use in accurate observations, corrections are required for temperature, humidity and variation in the force of gravity.

## QAUY WALLS AT ROTTERDAM.

From "Deutsche Bauzeitung."

OPPOSITE the town of Rotterdam, on the left bank of the Meuse, is the peninsula of Feijenoord, occupied by a large shipbuilding and iron-works company, by a station of the Dutch State railway, and by private and public buildings in

connection with the trade of the port. The railway possesses a large dock, the "Sporweghaven," 1,312 yards long and 109 yards wide. The Rotterdam Trading Company is now constructing a second basin about 1,092 yards long and from 43 feet to 82 feet wide. Both these docks are open or tidal basins; the average rise of the tide is only 3 feet 7 inches; the lowest tide in 1872 was 2 feet 9½ inches below zero, and the highest spring tide 5 feet 11½ inches above zero, the extreme range is therefore nearly 9 feet.

The flood tide runs for four hours, the ebb therefore about eight hours twenty minutes; the current is not strong. The nature of the soil is most unfavorable. Piles, 62 feet, 4 inches long, were driven without reaching solid ground; the soil is hardly strong enough for ordinary banks, and good sand has to be brought from a distance. It was, therefore, impossible to erect substantial quay walls on a masonry substructure, and piling was chosen as the only means of securing a permanent foundation. The construction adopted for the new basin is almost the same as the one used for the Sporweghaven, and is intended not only to secure the bank, but also to supply a wide quay, and considerable storage room for raw products and other goods.

The bottom of the basin is 19 feet 8 inches below zero, the top of the quay wall 9 feet 2 inches above it, the natural surface of the ground being about 9 feet 10 inches below zero. First, a wide ditch was dredged out to 23 feet below zero, with a slope of 1 to 1 both ways: this was filled with sand as soon as the mud was got out. Eight rows of piles were then driven, 4 feet 4 inches apart from center to center both ways, the front row being in line with the intended quay wall. These piles were from 52½ feet to 65½ feet long, and were cut off at the level of 4 feet 3 inches below zero. At a level of 11 feet 6 inches below zero, strong longitudinal bracing was introduced on both sides of each row of piles, and on the inside of the fourth row from the front a complete longitudinal wall of planks, ¼ inch thick, was erected parallel to the face, in order to ease the thrust on the front piles. Similar cross walls were run from this to the face at every

third row of piles, thus dividing the front half of the quay into a number of small compartments. The object of this was to diminish the effect of the current on the material of the slope, which was then completed from the level of 11 feet 6 inches below zero down to the bottom of the basin, and protected by a slight face and footing of stones. A substantial grid was constructed on the piles, and a platform of double planking, 3.15 inches thick, laid on it, braced horizontally above and below. The masonry wall was commenced over the whole width of 29 feet 6 inches, and carried up to a height of 1 foot 7 inches; the remainder of the height was, however, to be used as a warehouse. The foundations were stepped off in front and rear, so as to leave a face wall of 3 feet 11 inches thick at 1 foot 7 inches below zero, and a rear wall of 2 feet 6 inches at the same level.

The remaining clear space of 22 feet 7 inches was divided into three parallel galleries, by rows of columns resting on masonry, also stepped up from the foundations, so that the vertical section of the whole quay shows, roughly, two right-angled triangles on the face and rear, and two isosceles triangles filling up the space between them, and capped by the columns. The intervals between these triangles were filled up to a level of foot 7 inches below zero; for the floor of the warehouse. The columns consist of 4-inch gas-pipes filled with cement, resting on square cast-iron ribbed bed-plates, supplied with similar cast-iron caps. The latter carry rolled cross and longitudinal girders on which the road is laid. The Author indicates a batter of both face and rear walls, but the sketch is on too small a scale for the dimensions to be measured. After the completion of the masonry foundation, the slope was finished under the grid up to the fourth row of piles, and was covered with stones; earth was filled in behind up to the zero mark, and the rest of the basin was excavated.

The Author calculates the extreme load which can possibly come on each pile, and estimates it at 116 cwt.; which, reduced to square inches, and assuming the piles to average 12 inches diameter, is almost exactly 1 cwt. per square inch.

## FOUNDATIONS.\*

By JULES GAUDARD, Civil Engineer.

From Proceedings of the Institution of Civil Engineers.

## II.

Cylindrical foundations are sunk with or without the aid of compressed air according to circumstances. These foundations possess the two great advantages of being capable of being sunk to a considerable depth, and of presenting the least obstruction to the current.

In a clay soil the cylinder acts as a movable cofferdam, which is sunk by being weighted, and enables the foundations inside to be built up easily and cheaply. This method was first adopted by Mr. Redman, M. Inst. C. E., at Gravesend; and afterwards at the Charing Cross and Cannon Street bridges; and also for the piers of the Victoria bridge over the Thames. Iron cylinders are preferred in certain cases to cylinders of brick, masonry, or concrete, on account of the ease with which they are lowered in deep water on to the river bed; in spite of the disadvantages attaching to them of high price, of the considerable weights required for sinking them, and lastly, of being only cases for the actual piers.

In 1823, Sir Mark Brunel, in sinking the wells of access to the Thames Tunnel used linings of brickwork, 50 feet in diameter, and resting on iron frames with vertical tie-rods. At Rochefort, M. Guillemain used linings of masonry resting on plate-iron rings and strengthened by iron chains; the wells were made sometimes 10 feet, sometimes 13 feet in diameter, and it was found that the facility and rate of descent of the larger linings more than compensated for the additional material. At Lorient the Caudan foot-bridge was built on four large rectangular frames, sunk from 50 to 60 feet below high water. When the ground is very soft it has a tendency to run into these tubular cofferdams when the water is pumped out.

The method of sinking wells in India has been previously referred to. Mr. Imrie Bell, M. Inst. C. E., added a pole

to the jham used by the natives to save the trouble of diving, but even with this addition the process was slow. The foundations of the Poiney viaduct, on the Madras railway, were put in by this method. In more recent works the curb was made of iron instead of wood, and angular as in the case of the Jumna bridge. The first lengths were short, 5 to 6 feet, to insure a vertical descent; then a length of 10 feet, and afterwards lengths of 13 and 16 feet were added.

At the Glasgow bridge the lining was of cast-iron rings, being easier to lower in mid-stream; but for the quays and docks on the Clyde linings of brickwork and concrete were adopted for the sake of economy. Mr. Milroy, Assoc. Inst. C. E., considers that with concrete, which can be moulded to an edge at the bottom, all metal additions may be omitted where only silt or sand have to be traversed, and that the bottom ring should be of iron for penetrating harder soils. In the Clyde extension works the wells were filled up with concrete, and a double row of cylinders of 9 feet diameter were adopted in preference to a single row of 12 feet. It would be possible in this arrangement to take out the sand between the adjacent cylinders and form them into a solid mass by filling up these interstices with concrete. Mr. Ransome used cylinders of "apænite" for the Hermitage wharf on the Thames.

The Dutch engineers have often used oval-shaped iron tubes sunk by dredging inside. Thus in the bridge on the North Sea Canal the piers are elliptical; the one on which the opening portion turns having axes of 23 and 18 feet, and the others axes of  $39\frac{1}{2}$  and 14 feet. The horizontal flanges and ribs were larger where the radius of curvature is increased, and the vertical ribs are not continuous, but arranged so as to overlap. The bridge over the Yssel, on the Utrecht and Cologne railway, rests upon cylinders which were sunk by internal dredging  $17\frac{3}{4}$  feet below the river bed.

\* Translated from the French by L. F. Vernon-Harcourt, M.A., M. Inst. C.E.

In France sinking cylinders by dredging is not often resorted to in rivers, possibly owing to a failure of this system at Perpignan, where the sinking of a masonry cylinder by dredging was stopped by boulders, and compressed air had to be used. However, the foundations of bridges at Rivesaltes, and over the Saône at Lyons, and the jetty made at Havre in 1861, were executed by this method. For the walls of the wet dock of Bordeaux rectangular wells have also been sunk by dredging.

The extension of the system must depend chiefly on improvements in the dredging machinery, of which the successive steps in advance already attained may be noted.

The jham was suspended by Kennard's sand pump. With this machine a well,  $12\frac{1}{2}$  feet in diameter, was sunk in the Jumna 8 to 10 inches per hour by fourteen workmen. As the Kennard pump was not able to work in the compact clays and conglomerate met with in rebuilding the bridges over the Beas and the Sutlej Bull's dredger was adopted, which consists of a semi-cylindrical case with jaws opening in two quadrants, like the American dredger of Morris and Cummings.

Mr. Stone, M. Inst. C.E., however, mentions that when it met with a hard stratum a descent of only 2 feet 10 inches was accomplished in three months, whereas in the upper layer the progress was much more rapid than with the sand-pump.

Next came Mr. Milroy's "excavator," consisting of an octagonal frame from which are suspended eight triangular spades. These spades are forced vertically into the ground and are then lifted by chains so as to come together and inclose the earth, which can then be raised and discharged.

At the Glasgow bridge the progress was, on an average,  $11\frac{1}{2}$  feet per day, and the maximum 20 feet. At Plantation Quay the average for a cylinder was about 4 feet per day, but these cylinders were impeded in their sinking by tongues and grooves, so that double this rate might be reckoned on for unconnected cylinders. Another machine is the "screw pan" used at the Loch Ken viaduct, a conical perforated vessel, the diameter at the top being 2 feet, and

furnished at the bottom with a screw which enters the ground when turned.

The sand and mud entering the vessel are retained by little leather valves when the instrument is lifted. It works well in silt and clay; in harder soils a smaller vessel is needed.

Lastly there is the "boring head" used by Mr. Bradford Leslie, M. Inst. C.E., at the Gorai bridge. A revolving plane with blades underneath, able to disintegrate hard clays and compact sand, is worked inside the cylinder, and at the same time the excavated material is drawn up and removed from the cylinder by a siphon. To maintain an upward pressure in the siphon the level of the water in the cylinder is always kept higher than in the river. The boring-head made one revolution in about one minute and a half or two minutes, and excavated through clayey and sandy silt at a rate of about 1 foot per hour. One advantage possessed by this system is that the rate of progress is independent of the depth. The side piers of the Gorai bridge were sunk 124 feet below the surface, and the river piers 98 feet below low-water level. The only bridge the foundations of which have been carried down as deep as those of the Gorai bridge is the St. Louis bridge over the Mississippi; but the method of compressed air used in this work, looking at the difficulties and loss of life attending it, would have been impracticable with coolie labor at Gorai. The system of sinking by dredging is generally to be preferred to the compressed air system, except where numerous obstacles, such as boulders or embedded trees, are met with.

The friction between cylinders and the soil depends on the nature of the soil and the depth of sinking. For cast iron sliding through gravel the co-efficient of friction is between 2 and 3 tons on the square yard for small depths, and reaches 4 or 5 tons where the depth is between 20 and 30 feet. In certain adhesive soils it would be more. In sinking the brick and concrete cylinders in the silt of the Clyde it was found to amount to about  $3\frac{1}{2}$  tons per square yard.

Passing on to the consideration of the pneumatic systems, the process of Dr. Potts was one of the first employed for sinking tubular foundations by the help

of air. The cylinder in process of being sunk was connected with a vessel in which a vacuum was produced, and a communication between them being suddenly made a shock was produced by the rush of air. By this means Mr. Cowper, M. Inst. C.E., succeeded in driving down cylinders 5 feet at a time. The only novelty in the system was using air for applying a downward pressure on the cylinder, as dredging had still to be resorted to for removing the earth from the inside, and, moreover, there was a considerable influx of the surrounding soil, and frequent divergencies from the perpendicular. Mr. Bramwell, M. Inst. C.E., observing the effects produced by the rush of air out of the cylinder, in an aqueous soil, suggested sinking by forcing water from the interior of the cylinder towards its external surface, a process which would disintegrate the earth lubricate the sliding cylinder, and prevent the influx of the soil. The difficulties of the Potts process increase with the size of the cylinder; and for sinking the cylinders, 10 feet in diameter, of the Shannon bridge it was abandoned after an unsuccessful attempt.

The method of compressed air for enabling operations to be conducted under water is merely a modification of the diving-bell; but the application of it to a cylinder forced down by undermining was first made, in 1839, at Chalons for working a coal seam rendered inaccessible by the infiltrations of the Loire. After having begun the shaft by beating down a cylindrical lining of sheet iron, 3½ feet in diameter, it occurred to the engineer, M. Triger, to cover over the top of the cylinder, and by forcing air in to drive out the water and admit the workmen. An air chamber was formed at the top with double doors, serving as a sort of lock for the passage in and out of the cylinder of men and materials without giving an outlet to the compressed air, and a pipe running up the cylinder carried off the water from the bottom. In 1845 M. Triger sank another cylinder, 6 feet in diameter, in the same way, and suggested the employment of the method for the foundations of bridges.

The first bridge foundations of this kind were carried out, in the years 1851-52, at the Rochester bridge on the Med-

way, which has masonry piers each supported on fourteen cylinders, 6 feet 11 inches in diameter, filled with concrete. Having begun with the Potts process till on alighting on old foundations it proved useless, Mr. Hughes, M. Inst. C.E., conceived the notion of reversing the current of air, and sinking the cylinders by the help of compressed air. The success of this method recalled to mind earlier suggestions in the same direction, such as the patent of Lord Cochrane, in 1830, for excavating foundations by compressed air, and the suggestion of M. Colladon of Geneva to Sir M. Brunel to try to stop the rush of water into the Thames Tunnel by forcing in air.

At the Chepstow bridge foundations the late Mr. I. K. Brunel, Vice-President Inst. C.E., abandoned the Potts process on coming upon an embedded tree, and resorted to compressed air, which he also subsequently employed in commencing the foundations of the iron cofferdams used for the piers of the Saltash bridge.

The various details of the compressed air system are given in the descriptions of the works in which it has been employed. Theoretically, when the lower edge of the cylinder has reached a depth of  $h$  feet below the surface of the water, the pressure required for driving the

water out of the excavations is  $\frac{3.14}{h}$  atmos-

pheres; but frequently the intervention of the ground between the bottom of the river and the excavation enables the work to be carried on at a less pressure, as Mr. Brunel did at Saltash. A considerably greater pressure would be required if the water had to be forced from the excavation through the soil below the river bed; but this is avoided by placing a pipe inside to convey away the water, and M. Triger has found that the lifting of the water was facilitated by the introduction of bubbles of air into the pipe at a certain height.

Pressures of 2 or even up to 3 atmospheres do not injure healthy and sober men, and suit best men of a lymphatic temperament, but prove injurious to men who are plethoric or have heart disease. It is advisable to avoid working in hot weather, and each workman should not work more than four hours per day, or more than six weeks consecutively. At

Harlem, New York, however, workmen have remained ten hours under a pressure of 50 feet, and even 80 feet of water. On the other hand, at St. Louis under a pressure of little more than 3 atmospheres several men were paralyzed or died, and the period of work was gradually reduced from four hours to one hour. From experiments on animals M. Bart has found that the accidents caused by a sudden removal of pressure are due to the escape of the excess of gas absorbed by the blood. Beyond 6 atmospheres any sudden return to the normal pressure is attended with danger; the usual rule now is to allow one minute per atmosphere. The cylinders subjected to pressure should be furnished with safety valves, pressure gauges, and alarm whistles, as explosions occasionally occur.

Iron rings from 6 feet to 13 feet in diameter are cast in one piece, and a caoutchouc washer is introduced at the joints between the rings; cylinders of larger diameter are cast in segments, and cylinders of smaller diameter than 6 feet are rarely used. The thickness is usually  $1\frac{1}{8}$  inch, increased to  $1\frac{1}{2}$  inch or  $1\frac{3}{4}$  inch were exposed to blows, in conical joining lengths, and in the bottom length.

When two cylinders have to be sunk close together it is best to sink them alternately, as they tend to come together when sunk at the same time. At Macon, where there was only an interval of  $3\frac{1}{2}$  feet between two cylinders, one of the cylinders was seen to rise suddenly as much as 6 feet when the other was forced down. Sometimes where cylinders of small diameter have to be used the excavations are extended beyond the cylinder at the bottom, and filled with concrete to give a greater bearing surface; this plan was adopted at Harlem bridge, New York, and by the late Mr. Cubitt, Vice-President Inst. C.E., at the Blackfriars railway bridge. Another way of accomplishing the same object is by enlarging the lower rings of the cylinder, and putting in a connecting conical length, as was done by Sir John Hawkshaw, Past-President Inst. C.E., at the Charing Cross and Cannon Street bridges.

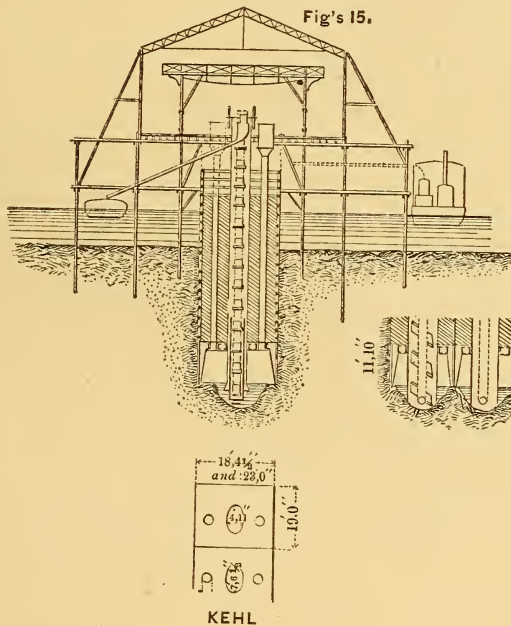
The cylinders at Bordeaux were forced down by MM. Nepveu and Eiffel, in

1859-60, by strong beams of wrought iron, moved up or down by the pistons of four hydraulic presses, having 11 feet length of stroke and exerting a pressure of 60 to 70 tons; the force could be applied at pleasure, and regulated according to circumstances. At Argenteuil, where cylinders 12 feet in diameter had to be sunk, the concreting inside was carried on during the sinking, leaving only a circular shaft in the center, 3 feet 7 inches in diameter, lined with wooden framing, and enlarged at the bottom to a conical shape by a sort of cage of inclined beams butting against the bottom of the shaft (Fig. 18). The cylinders were sunk 50 feet on the average below low-water level, through mud, sand, gravel, and clay, on to marl or limestone, and four screw-jacks of 20 tons power supported the bottom ring by means of flat iron straps. After the sinking was completed the chamber at the bottom was filled with cement concrete, poured around iron pipes placed near the sides so as to maintain the pressure of air during the operation. When this layer of concrete was set the pipes were closed with cement, the normal pressure restored, and the shaft filled up with concrete. Concrete deposited under compressed air appears to set quicker, and to increase somewhat in strength, provided it is deposited in thin layers allowing the excess of water to escape. At Szègedin this was effected by mixing very dry bricks with the concrete. At Perpignan the foundations of a bridge over the Tet had been commenced by sinking a masonry cylinder by dredging inside, but large stones being unexpectedly met with the method of compressed air had to be resorted to. The masonry cylinder,  $3\frac{1}{2}$  feet thick and 13 feet outside diameter, with a batter outwards of 1 in 100, was lined inside with neat cement, and was covered with a plate-iron top  $\frac{1}{8}$  inch thick. The sinking was assisted when necessary by letting out air; the depth attained was about 26 feet. The cylinder was filled with concrete, which for the first  $6\frac{1}{2}$  feet was deposited under pressure. The success attending this experiment has led M. Basterot to recommend the deliberate application of compressed air to masonry cylinders for depths of less than 33 feet below water, and he estimates the cost

of such a cylinder, 13 feet in diameter, sunk by this method 26 feet deep and filled in, at £340.

The foundations of the piers of the Kehl bridge were accomplished by the engineers, MM. Fleur Saint-Denis and Vuigner, by a combination of the principles of the compressed air process, the sinking of a pier by its own weight, the sinking by dredging, and the cofferdam system. As the bed of the Rhine at Kehl consists of large masses of gravel liable to be disturbed to a depth of 55 feet below low-water level, it was deemed advisable to carry the foundations down about 70 feet below low water. For the two central piers the chamber of excavation was divided into three

caissons, the length of each being 18 feet 4 inches, the width of the foundation. For the piers forming the abutments for the swing bridges there were four caissons, each 23 feet long, the breadth of all the caissons being 19 feet. The plate iron forming the caissons was  $\frac{3}{8}$  inch thick at the top, and  $\frac{5}{16}$  inch thick at the sides, and strengthened by flanges and gussets. The top was strengthened by double T beams for supporting the weight of the masonry above. There were three shafts to each caisson, two being air shafts,  $3\frac{1}{4}$  feet in diameter, one being in use whilst the other was being lengthened or repaired; the other shaft in the center was oval, open at the top and dipping into the water in the foun-



dations at the bottom, so that the water could rise in it to the level of the river. In this shaft a vertical dredger with buckets was always working, and the laborers had only to dig, to regulate the work, and remove any obstacles. The screw-jacks controlling the rate of descent had a power of 15 tons, and were in four pairs. The wooden framing serving as a cofferdam was erected above the chamber of excavation; it was useful at the commencement for getting below the water, but might subsequently have been dispensed with. It was also

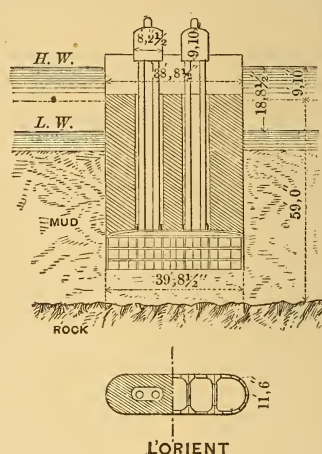
found by experience that the caissons were sunk better in one division than in several divisions, and doors of communication were accordingly made through the double partitions. The iron linings to the air shafts were removed before the shaft was filled up. The shaft containing the dredger was at first made of iron, but afterwards of brick for the sake of economy. The sinking occupied sixty-eight days for one abutment, and thirty-two days for the other, giving a daily rate of 1 foot 1 inch and 1 foot  $8\frac{1}{2}$  inches respectively. The sinking of

the caissons for the intermediate piers took twenty to thirty days, which gives a daily rate of two feet  $7\frac{1}{2}$  inches (Fig. 15).

For large works, where the load on the foundations is considerable, carrying down the foundations to a hard bottom is much better than piling. The dredger used at Kehl cannot be regarded as universally applicable. Some soils are not suitable for dredging, and in other cases the small amount of excavation renders the addition of an extra shaft inexpedient, as for instance at Lorient. The chamber of excavation is almost invariably made of plate iron, but, unlike those at Kehl, with the iron beams above the ceiling, instead of below, so that the filling in may be accomplished more easily. The cutting edge is always strengthened by additional plates. At Lorient the thickness was  $2\frac{3}{16}$  inches, with several plates stepped back so as to form a sort of edge; the sides were about  $\frac{1}{2}$  inch thick at the bottom, and  $\frac{5}{16}$  inch at the top, and the roof was curved a little to increase its strength. At Vichy the plates were about  $\frac{1}{2}$  inch thick. At La Voulta, Hollandsch Diep, and Lucerne, a sort of masonry lining was placed against the iron plates, and kept in place by gusset plates, to afford greater rigidity against the pressure of the earth. At St. Maurice wooden struts were substituted for angle-iron flanges; and at Vichy struts were put in at the base of the caisson, and also half-way up to support the sides. In consequence of these modifications, the caisson at Lucerne ( $55\frac{3}{4}$  feet by  $13\frac{3}{4}$  feet) weighed only 28 tons; the caisson at St. Maurice ( $32\frac{3}{4}$  feet by  $14\frac{1}{2}$  feet) weighed 14 tons; whereas at Kehl, a caisson, 23 feet by 19 feet, weighed 34 tons; at Lorient ( $39\frac{1}{2}$  feet by  $11\frac{1}{2}$  feet) weighed  $27\frac{1}{2}$  tons; and at Riga ( $64\frac{1}{2}$  feet by 16 feet) weighed  $45\frac{3}{4}$  tons. The height of the chamber of excavation should be about 8 feet 10 inches. Frequently the cofferdam casing is of iron, as at Kehl, which protects the newly-built masonry from friction; and the upper portion of the casing can be removed when the work is completed. In a sea bed, with a silty bottom, special precautions must be taken against overturning, as variations in weight, according to the depth of immersion, are added to the effects of the current. Some di-

vergence from the perpendicular at Lorient was due partly to this cause, but partly also to the absence of supporting screw-jacks. At Lorient there were two air locks, each connected with two shafts, in which balanced skips went up and down (Fig. 16). On the top of the bot-

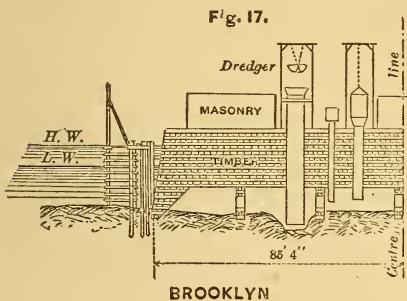
Fig's 16.



tom caisson a casing of sheet iron, from  $\frac{3}{16}$  to  $\frac{1}{8}$  inch thick, and weighing about 15 tons, was erected in successive rings. At the Nantes bridges, built in 1863 by M. M. Gouin for the railway of Roches-sur-Yon, twenty-two caissons were erected, and the depth of the concrete foundations varied from 39 to 62 feet. The same firm were the contractors for the pneumatic foundations at Hollandsch Diep for three piers, two being carried about 80 feet below high-water level, and the other 65 feet. As the river bed was very soft down to 50 feet below high water, and injury from storms might be apprehended, it was necessary to perform the first part of the sinking as rapidly as possible. The working chambers, and the lower 16 feet of the caisson, and the shafts for 23 feet in height, were erected on the bank, and masonry built on the horizontal projections of the chambers. Each caisson was then slid down an inclined plane to low-water mark, and at high water two boats fastened together removed them to their proper site, where they were deposited and gradually sunk into the ground. The excavation, the building up of the masonry, and the addition of successive

lengths to the caisson, were carried on simultaneously. As the earthwork was easily removed, the caissons sank at a rate of from  $1\frac{1}{2}$  foot to  $3\frac{1}{4}$  feet per day. The first two piers were each completed in forty-five days from the launching of the caissons.

The Americans have adopted the pneumatic system for some large works, and introduced improvements. At the St. Louis bridge the foundations were carried to a greater depth than had ever been previously attained; and at East River bridge compressed air was used in wooden caissons of large dimensions. The particulars of the St. Louis bridge have been given by Mr. Francis Fox, M. Inst. C.E. The hydraulic sand pumping tube of Mr. Eads must only be recorded. The following details of the East River bridge are derived from the treatise of M. Malézieux, previously referred to. The Brooklyn pier was to be carried 50 feet and the New York pier 75 feet below high water. To provide against unequal sinking, owing to the variable nature of the soil, consisting of stiff clay mixed with blocks of trap rock, Mr. Roebling decided to place the bottom of the piers upon a thick platform of timber which formed the roof of the working chamber (Fig. 17). The sides were also



made of wood, as being easier than iron to launch and deposit on the exact site. The roof consisted of five tiers of beams, 1 foot deep, of yellow pine, placed one above the other and crossed, the beams being tightly connected by long bolts. The working chamber was 167 feet by 102 feet, and 10 feet clear height. The side walls had a V section, with a cast-iron edge covered with sheet iron; the walls had a batter inside outwards of 1 to 1, and 1 in 10 on the outside. Five

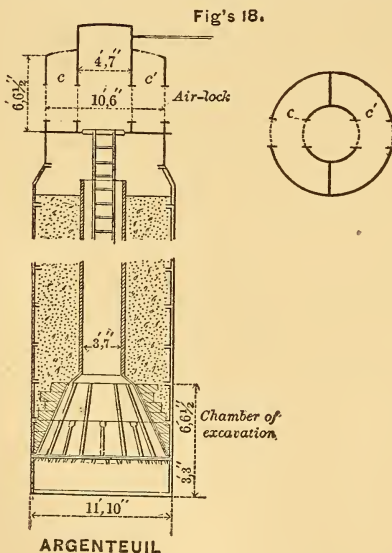
transverse wooden partitions, 2 feet thick at the bottom, served to regulate the sinking. When the caisson had been put in place, twelve tiers of beams were added on the roof of the chamber of the Brooklyn pier, and nineteen on that of the New York pier, so that the top rose above water, and the masonry could be built without a cofferdam lining. The excavation, to the extent of 19,600 cubic yards, was performed in five months by Morris & Cumming's scoop dredger, working in two large shafts, dipping into the water at the bottom, and open above. When hard soil was met with these shafts were shut, and the excavation performed by manual labor under compressed air. In the New York caisson the total number of shafts was nine. The blocks of trap rock impeded the progress considerably; they had to be discovered by boring, and shifted or broken before the caisson reached them. When under 26 feet of water they could be blown up; this enabled the rate of progress, which had been 6 inches per week, to be doubled or trebled. When the caisson had reached a compact soil, it was possible to reduce the pressure to two-thirds of an atmosphere in excess of the normal pressure, and water had occasionally to be poured into the open shafts to maintain the proper water-level in them. By frequent renewal of the air, a supply was furnished for one hundred and twenty men and for the lights; and the temperature was kept nearly constant throughout the year at  $86^{\circ}$  within the caisson, whilst in the open air it varied from  $108^{\circ}$  to  $0^{\circ}$ . As the load increased as the caisson went down, the roof of the Brooklyn caisson was eventually supported by seventy-two brick piers, so that the caisson might not become deeply embedded in the event of a sudden escape of air. In the New York caisson two longitudinal partitions were added, which served the same purpose.

In the silty sand which was frequently met with, a discharge pipe, up which the sand was forced by compressed air, proved very useful, discharging a cubic yard in about two minutes. The New York caisson (170 feet by 102 feet) was sunk in five months; the earthwork removed amounted to 26,000 cubic yards. The cheapness of wood in America per-

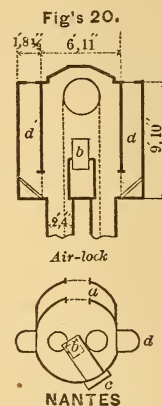
mits a much freer use of it there than could be attempted in Europe.

When the watertight nature of the lower soil in the foundations of the East River bridge is considered, coupled with the inconveniences experienced in working under compressed air, as shown at the St. Louis bridge, it seems probable that in some future large work it may be possible to commence sinking a large caisson with compressed air, and after a better stratum is reached open all the shafts. The operation could then be completed by pumping out the small amount of water that might come in, and excavating in the ordinary way, as is often done in England, on a small scale, where the excavation to sink the cylinders to a water-tight stratum is performed by divers. If, as M. Morandière suggests, the air-lock was placed close over the working chamber, or even inside it, which would save constant alterations and allow of its being of larger dimensions, it would be desirable to have a special air-lock at the top, so that in the event of an accident the men might run up the shaft without the delay occasioned by passing through the air-lock. At Bordeaux the air-lock was formed by fixing one circular plate at the top and another at the bottom of

should be opened very seldom, or made very small if required to be opened often. At Argenteuil the air-lock had an annular form (Fig. 18) with two compartments C, C', each having an external and an internal door. One compartment was put in communication with the interior to be filled with the excavated material, whilst the other was being emptied by the outer door, so that the loss of air was diminished without any interruption to the work. Sometimes a double air-lock with one large and one small compartment is used; the large one being only opened to let gangs of workmen pass, and the small one just big enough to admit a skip and to contain a little crane for moving it. By having a small air-lock opened frequently, any sudden alterations in pressure are diminished. A more complete arrangement was adopted at Nantes (Fig. 20). There a sheet-iron cylinder was

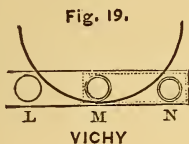


one of the rings of the cast-iron cylinder, so that it was unnecessary to remove it each time that an additional ring was added. To save loss of air the air-lock



placed on the top of the double shaft in which the skips worked, having at one side a crescent-shaped chamber, *a*, serving to pass four men, and also on either side two concrete receivers, *a*, *a'*, having doors above and below. There was also a shoot below for turning the concrete into the foundations, and a box, *b*, *c*, holding a little wagon which emerges at *c* after having been filled from an upper door, *b*. This last contrivance resembles that devised at Vichy by M. Moreaux (Fig. 19). The cast-iron box L, N, going across a segment of the air chamber, has three orifices, L, M, N, and a drawer with two compartments slides inside it. If these compartments are at M and N, the left one at M is filled whilst the

other at N is emptied. Then by a rack movement the drawer is pushed back till



the compartment to the right comes to the center of the box, that is to say, into the air-lock, and the other is emptied outside at L. At Rotterdam, M. Michaëlis put a little inclined trough at the bottom of the principal air-lock, and closed it at each extremity by a valve, so that it both formed a little independent air-lock and also a shoot for the excavation. Mr. Smith employed the same system at the Omaha bridge over the Missouri. By not permitting the earth-work to enter the principal air-lock, it was possible to keep six great glazed bull's-eyes clean, by which both the daylight was admitted and at night the light was thrown from a reflector. The use of lamps inside, smoking and giving a bad light, was thus dispensed with.

The Author next proposes to give some details of the cost of foundations constructed by the help of compressed air. At Moulins cast-iron cylinders, 8 feet  $2\frac{1}{2}$  inches in diameter, with a filling of concrete and sunk 33 feet below water into marl, cost £12 18s. 6d. per lineal foot, or £6 2s. for the ironwork, and £6 16s. 6d. for sinking and concrete. At Argenteuil, with cylinders 11 feet 10 inches in diameter, the sinking alone cost £8 13s. 2d. per lineal foot, and one cylinder was sunk  $53\frac{1}{2}$  feet in three hundred and ninety hours; and at Orival, £7 12s. 5d., where the cylinder was sunk 49 feet in twenty days. At Bordeaux, with the same sized cylinders, a gang of eight men conducted the sinking of one cylinder, and usually 34 cubic yards were excavated every twenty-four hours. The greatest depth reached was  $55\frac{3}{4}$  feet below the ground, and 71 feet below high water. In the regular course of working, a cylinder was sunk in from nine to fifteen days, and the whole operation, including preparations and filling with concrete, occupied on the average twenty-five days. One cylinder, or a half pier, cost on the average £2,320, of which £300 was for sinking. M. Morandière

estimates the total cost of a cylinder sunk like those at Argenteuil, at a depth of 50 feet, at £1,440.

Considering next the cost of piers of masonry on wrought-iron caissons of excavation; the foundations of the Lorient viaduct over the Scorff cost the large sum of £4 19s. per cubic yard, owing to difficulties caused by the tides, the labor of removing the boulders from underneath the caisson, and the large cost of plant for only two piers. The foundations of the Kehl bridge cost still more, about £5 16s. per cubic yard; but this cannot be regarded as a fair instance, being the first attempt of the kind.

The foundations of the Nantes bridges, sunk 56 feet below low-water level, cost about £3 1s. per cubic yard. The average cost per pier was as follows:

Caisson (41 feet 4 inches by 14 feet 5 inches), 50 tons of wrought-iron at £24	1,200
Cofferdam, 3 tons of wrought-iron at £12	36
Excavation, 916 cubic yards at 18s. 4d.	840
Concrete.....	860
Masonry, plant, &c.....	384
	<hr/> £3,320

One pier of the bridge over the Meuse at Rotterdam, with a caisson of 222 tons and a cofferdam casing of 94 tons, and sunk 75 feet below high water, cost £14,550, or £2 17s. 5d. per cubic yard.

The Vichy bridge has five piers built on caissons, 34 feet by 13 feet, and the abutments on caissons 26 feet by 24 feet. The foundations were sunk 23 feet in the ground, the upper portion consisting of shingle and conglomerated gravel, and the last 10 feet of marl. The cost of the bridge was as follows:

Interest for eight months and depreciation of plant worth £4,000.....	800
Cost of preparations, approach bridge and staging.....	1,007
Caissons, No. 7, $150\frac{3}{4}$ tons at £23 6s.....	3,513
Sinking.....	2,017
Concrete and masonry.....	1,089
Contractor's bonus and general expenses	1,254
	<hr/> £9,680

The cost per cubic yard of foundation below low water was £3 8s. 7d., of which the sinking alone cost 15s. 3d. in gravel, and 19s. in marl. At St. Maurice the cost per cubic yard of foundation was £3 5s. 6d., exclusive of staging.

The Author has treated of the subject of tubular foundations at some length,

because they are the most effectual means at the disposal of engineers for carrying foundations to great depths below water. Economical considerations render it desirable to adopt pumping or dredging when possible; but compressed air is very serviceable where boulders or other obstacles are met with, or where, as at Vichy, the ground is conglomerated and unsuitable for dredging. In cases where the proper course to be adopted is a matter of doubt, the success at the Gorai bridge, and the power of resorting to the aid of divers, if necessary, would encourage an attempt being made to dispense with compressed air, which at great depths, such as 100 feet under water, is attended with danger. The Tet bridge, moreover, furnishes an example of the possibility of resorting at last to compressed air if found indispensable.

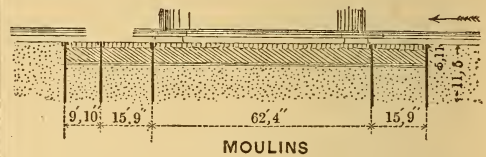
In soft ground of unknown depth the best methods for making foundations are those already described; but it is sometimes advisable in small works to adopt more economical methods. Two distinct cases have to be considered:—  
1. Where the soil is firm, but liable to be scoured to great depths; 2. Where the soil is soft as well as exposed to considerable scour.

Régemortes gained a reputation by his method of dealing with an instance of the first of these two cases at Moulins, where several bridges had been destroyed one after another by scour in floods, owing to the piles on which they rested being unable to penetrate far enough

into the firm sand composing the bed of the Allier.

Régemortes, in 1750, renounced the idea of finding a stable foundation far down, and built on the surface, rendering it secure from scour by covering it with a masonry apron. The apron, having a uniform thickness of 6 feet (Fig. 21),

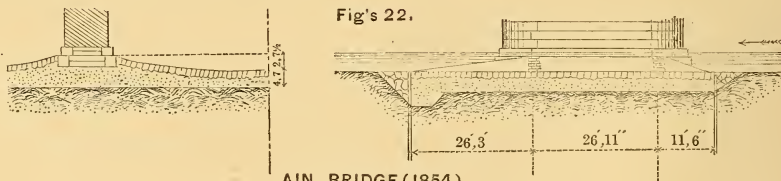
Fig. 21.



MOULINS

was laid on the dredged and levelled bed, dried by diverting the stream, or, in some places, by inclosing it with timber and pumping out the water. The infiltration through the bottom was stopped by depositing a layer of clay all over, and then lowering caulked timber panels in it. This method has, however, been much simplified by the introduction of hydraulic concrete. The apron at the West Viaduct at Amsterdam consists of a layer of concrete, 4 feet thick, placed on piling, and protected at the ends by sheeting. The apron of the Guétin canal bridge, constructed by M. Jullien in 1829, is 69 feet wide, 5 feet 5 inches thick, and 1,640 feet long. The concrete was carried down to a depth of  $11\frac{1}{2}$  feet at each end between two rows of sheeting  $6\frac{1}{2}$  feet apart. Another form of apron was adopted at the Ain bridge (Fig. 22), with a single row of sheeting

Fig's 22.



AIN BRIDGE (1854)

at each end,  $26\frac{1}{4}$  feet from the facing of the bridge at the lower end, and  $11\frac{1}{2}$  feet at the upper end. The lower or down-stream ends of the apron were always the most secured against scour, in the belief that a cavity would be formed below by the scouring away of the sand, but that above the currents would bring down sand and fill up any hollows that might have been scoured out. The in-

vestigations however, of MM. Minard and Marchall on the floods of the Loire and the Allier in 1856 indicated that the upper end of the apron is most exposed to scour and requires most protection, as the river bed close to the lower end is protected by the apron, whereas at the upper end the river bed is exposed to the full force of the current where the obstructions of the piers produce whirl-

pools. The apron of the Ain bridge cost £7 15s. 9d. per square yard of clear roadway above, or nearly as much as the bridge which it supports.

In certain instances the movable bed of a river has been sufficiently consolidated at the site of a work by merely a thick layer of rubble stones thrown in, giving time for the stones to take their final settlement during floods. Lastly, a movable bed can be consolidated by a wooden stockade; one of these was made, in 1820, below Amboise bridge, like the one Perronet had put down under the Orleans bridge in 1761, and both have stood perfectly.

The second case of a soil both soft and liable to scour has next to be considered. Where considerations of expense forbid going down to the solid, the following methods have been adopted:

(1) The ground is sometimes consolidated by driving a number of piles close together, or by covering it with rubble stones with or without fascine-work, so as to form a kind of superficial crust capable of bearing the structure. It is, however, generally advisable to break through the superficial stratum, and to produce a compression extending down a considerable depth by a large weight of earth, as was done for the railway bridge crossing Lake Mälär at Stockholm, where there is a thickness of 69 feet of silt under 79 feet of water. A large embankment of sand was tipped in and inclosed by sheeting, within which close rows of piles were driven, and then a water-tight caisson was lowered on a platform sunk  $3\frac{1}{4}$  feet below the water, in which the foundations were commenced.

(2) Another method is to increase the bearing surface at the base by large footings, or by timber platforms, layers of concrete, bedding courses of masonry, or rubble stone.

(3) The weight of the superstructure can be diminished by forming hollow cells in the masonry, or by using iron girders instead of stone arches.

(4) In heterogeneous strata the weight must be distributed as much as possible in proportion to the bearing power at different points.

(5) It is advisable sometimes to inclose the site of the foundations with

sheeting, walls, &c., not only as a protection against scour, but also to prevent the running-in of the soil from the sides when a weight is brought on it.

The Cubzac suspension bridge over the Dordogne furnishes a good example of a successful surmounting of difficulties in foundations. The suspended roadway was made as light as possible; the piers were hollow and perforated cast-iron columns, resting on a stone base supported by piles from 40 to 62 feet long, and 2 feet  $7\frac{1}{2}$  inches apart. The abutments and anchorage masonry were built with arched openings and light invert, and the embankments at each end were of light limestone blocks arranged in rough arches so as to form hollow spaces in the mass.

Although in this enumeration of the different kinds of foundations bridges have generally been chosen for examples, the methods described would be applicable to other works; such as large locks, graving docks, and quay walls.

The difficulties attending the laying of lighthouse foundations, and the means adopted to surmount them, are fully detailed in descriptions of these works.

In sea works the chief difficulties are encountered above the foundations where the sea breaks against the structure, and accordingly the methods of protection adopted do not come within the limits of this Paper. But the valuable addition to the methods of foundations used for these works by the introduction of concrete blocks, which can be formed of almost any size, and deposited by divers, must not be overlooked.

The effect of pumping or hammering action referred to by Mr. W. Parkes and Sir John Coode (vol. xxxvi., Minutes of Proceedings Inst. C.E., pp. 234 and 240) is due to the immersion and emersion during the oscillation of waves. Perhaps to this cause may be partially attributed the fall of a quay wall at Vevey in the present year. This wall was founded with a base of concrete contained in metallic boxes resting on high timber piles.

M. Croizette Desnoyers has framed a classification of the methods of foundations most suitable for different depths, and also an estimate of the cost of each. These estimates, however, must be considered merely approximate, as unfore-

seen circumstances produce considerable variations in works of this nature.

		Per cubic yard.	
		Depths.	s. s.
Foundations on piles after compression of the ground.....	{	20 to 33 feet....	12 to 18
		33 to 50 feet....	18 to 30
Foundations by sink- ing wells.....	{	33 to 50 feet....	30 to 37
Foundations by pumping.....	{	under 20 feet....	12 to 18
		26 to 33 { favorable circumstances.	18 to 55
		feet { unfavorable .....	61 to 73
Foundations on con- crete under water.	{	20 to 33 ft. small amount of silt.	18 to 37
		26 to 33 ft. large amount of silt.	37 to 49
Foundations by means of compressed air under favorable circumstances....55 to 67			
Foundations by means of compressed air under unfavorable conditions.....	{	Lorient viaduct..	99
		Kehl bridge.....	122
		Argenteuil bridge	140
		Bordeaux bridge.	165

When the foundations consist of disconnected pillars or piles the above prices must be applied to the whole cubic content, including the intervals between the parts, but of course for an equal cost solid piers are the best.

For pilework foundations the square yard of base is probably a better unit than the cubic yard. Thus the foundations of the Vernon bridge, with piles from 24 to 31 feet long, and with cross timbering, concrete, and caisson, cost £14 7s. 7d. per square yard of base. According to estimates made by M. Picquenot, if the foundations had been put in by means of compressed air the cost would have been £32 15s. 7d.; with a caisson, not watertight, sunk down, £13 12s. 2d.; with concrete poured into a space inclosed with sheeting, £12 15s. 7d.; and by pumping £17 3s. 2d. per square yard of base.

M. Desnoyers gives the following recommendations with regard to the choice of methods:

(1) In still water to construct the foundations by means of pumping for depths under 20 feet. In greater depths to construct ordinary works on piles if the ground is firm or has been consolidated by loading it with earth; otherwise to employ pumping, and if a permeable stratum is met with to build on it with a broad base. For important works, if the soil is watertight, it is advisable to adopt the method of pumping inside a framing, carrying down the

foundations to greater depths than 33 feet by the well-sinking method. If the soil, however, is permeable, dredging and concrete deposited under water must be resorted to; compressed air being employed for depths greater than 33 feet.

(2) In mid-stream compressed air must be resorted to for foundations more than 33 feet below water. In less depths the foundations of ordinary works are put in by means of dams or watertight frames if the nature of the silt admits of pumping out the water; but if the silt is permeable a mass of concrete is poured into the site inclosed by sheeting. When, however, an important work has to be executed, it is desirable to use pumps sufficient to overcome the infiltrations. If a permeable and easily-dredged stratum lies between the hard bottom and the silt the method of a watertight casing, with a dam at the bottom, should be adopted. To complete these recommendations open cylindrical foundations must be included. These may be resorted to, instead of compressed air, when the soil is readily dredged or watertight enough to allow of pumping, and also frequently in the place of piles or the well-sinking method. The compressed air system is essentially a last resource, applicable to a bed exposed to scour, and also either difficult to dredge or with boulders or other obstacles imbedded in it.

In conclusion, a chronological list of works is added to show at what periods the principal steps in advance were made.

The system of rubble mounds is the most ancient; and dams of earth came into vogue in the seventeenth century. In 1500-1507, the "Notre Dame" bridge at Paris was founded on piles surrounded with heavy rubble stones. In 1716 the Blois bridge was built on piles and a platform at low-water level. The method of constructing a foundation by means of an apron was introduced by Régemortes at Moulins in 1750. At the same time Labelye built the foundations of the old Westminster bridge by sinking caissons in the dredged bed of the Thames, a similar process having been adopted, in 1686, for the pier of the Tuileries bridge next the right bank of the Seine. In 1756 Des Essarts invented

a saw for cutting off piles under water, which enabled a caisson to be deposited on piles for the Saumur bridge, a method thenceforward adopted for the bridges at Paris till 1857, also for the Sèvres, Ivory, and Bordeaux bridges, and old Blackfriars bridge was built in the same way.

In the year 1818 Vicat discovered the properties of hydraulic mortars, and the adoption of a concrete foundation deposited inside sheeting soon followed; also the bottomless frame system with concrete at the bottom, first used by Beaumoulin for several bridges at Paris, and adopted for the bridge over the Cher.

In 1833-40 Poirel employed for the first time artificial blocks of concrete at Algiers harbor. He also used caissons with a bottom of canvas for depositing liquid concrete *in situ*.

M. Triger first used compressed air at the Chalons coal mine in 1839; and Dr. Potts introduced his system in 1845.

The tubular method of foundations was next introduced, and under various forms is continually becoming more universally adopted. The following are

the dates of some of the works for which it was used:—

Gravesend cofferdam. Mr. J. B. Redman.....	1842
Rochester bridge. Mr. Cubitt.....	1851
Saltash bridge. Mr. I. K. Brunel....	1854-57
Kehl bridge. Messrs. Fleur St. Denis and Vuigner.....	1853-59
Charing Cross bridge. Sir J. Hawkshaw.....	1860
Cannon Street bridge. Sir J. Hawkshaw.....	1863
Victoria bridge. Sir Charles Fox....	1863

In 1867 Kennard's sand-pump was used for the foundations of the Jumna bridge.

The "boring-head" was used by Mr. Leslie in 1867-70 at the Gorai bridge, and at the same time Mr. Milroy introduced his "excavator."

Lastly, between 1870 and 1873 the Americans laid the foundations of the St. Louis and East River bridges, whilst Mr. Stoney, by depositing huge blocks in the Liffey, and Mr. Dyce Cay, by depositing concrete *in situ* in large masses at the Aberdeen break-water, extended the methods of employing concrete in river and sea works.

## PROGRESS OF THE SLAG INDUSTRIES DURING THE LAST FOUR YEARS.\*

By Mr. CHARLES WOOD.

From "Journal of the Society of Arts."

It is now four years since I had the honor to read before you a short paper upon the "Utilization of Blast Furnace Slag."

I am not aware that at that time (with the exception of the use of slag for road metal) there was a single instance in this country of slag being successfully manufactured into a commercial commodity, although, as I have mentioned in a paper read before another society, nearly 60 different systems had been patented or tried, resulting only, in many cases, in disappointment, after enormous expenditure of both time and money.

At the present moment I can point out nearly a dozen different classes of

goods into which slag is being manufactured, whilst the different uses to which some of these products are being applied are very various, and are daily on the increase. I have, at the end of this paper, appended a small list, showing a few of the forms into which blast furnace slag is being made, and to what purposes it is being applied.

In my former paper I showed you how the slag properly prepared might be employed, but I had nothing to confirm what I there stated. I will now try to prove that all I then suggested has been fully realised, and I will show that the manufacture of slag into mortar, cement, building bricks, and a superior concrete (which will set perfectly in water) is now being carried on at Middlesbrough,

\* Paper read before the Iron and Steel Institute at Newcastle.

and, even in these bad times, at a reasonable profit.

In the first place, I may mention that, at the Tees Iron Works, there are three slag sand machines and two slag shingle machines working, and these machines have produced not far short of 100,000 tons, all of which has been utilized in a profitable manner.

In order thoroughly to test the value of slag made by my two machines for the various purposes just mentioned, it was thought advisable to form a company that should take up the manufacture as a specialty, and who could devote the time and attention so necessary to a young and untried industry. This company has now been in operation about two years and a half, and, like most new concerns when attempting the manufacture of a fresh material, it has had to pass through a severe ordeal. The difficulties met with have been numerous. The failure of one machine after another, the loss of time, patience, and money, would have ruined many private individuals, but thanks to Messrs. Gilkes, Wilson, Pease, and Co., and to a few friends in the Slag Company, I have been enabled to pass through the ordeal, and I am thankful to say that neither their confidence, money, nor time is likely to be lost; but that there is every probability that, with a larger output and a revival of trade, their capital will receive a fair dividend.

The Cleveland Slag Company's works are situated near the docks at Middlesbrough, and are now paying between £60 and £70 per week in wages. The most important part of their manufacture is slag bricks for building purposes, made from the slag sand, produced by the slag sand machines at the blast furnaces. This sand is mixed with selenitic lime (General Scott's patent), with an addition of iron oxide, and is pressed in a machine hereafter to be described.

The next article of importance manufactured at these works is a kind of hydraulic cement, made from the slag sand, common lime, and iron oxides. Compared with Portland cement for hydraulic work or concrete, this is the most valuable product introduced for many years, whilst its price is not one-fourth, and the strength little inferior.

Concrete made from this cement, mixed with the shingle produced from the rotary table, is an excellent conglomerate for use in monolithic structures. With this material I have executed some very heavy blast engine foundations—in one case where brickwork set in cement had previously failed. The concrete is now standing in the most perfect manner. The cost of the concrete is only about one-fourth that of the brickwork, and experience has shown that it goes on hardening for months. The building of the Slag Company's works is executed entirely in this material—the walls being nearly 80 feet high—they were built entirely by laborers, without a single bricklayer, and the cost of the work when finished, including superintendence, did not exceed six shillings per cubic yard. To give an idea of the strength of the walls, I may mention that on one or two occasions we have had to cut doorways through them, and it has taken two good men with steel bars and sledge hammers as much as four days to cut through a thickness of about twenty-six inches.

Mortar is also made and sold in large quantities from a mixture of slag sand, and about 10 per cent. of common slaked lime, and it can be sold at the cheap rate of about 4s. per ton.

The introduction of these various products from slag at first met with a good deal of opposition and prejudice from architects and builders, but the remarkable strength and cheapness of the material soon compelled these gentlemen to admit their error, and I am happy to say that our demand in some instances is now more than the production.

As before stated, the most important branch of the business carried on by the Cleveland Slag Company is the manufacture of building bricks, and, although the process is now very simple, it has been here that the greatest difficulties have occurred. There was no machine made in England that could work the material in the state in which it is produced at the furnaces, without previous preparation; and to prepare the material to suit the brick press meant that the cost of the bricks became so high as to exclude them from the market. A press had, therefore, to be designed that would work the slag sand just as it comes from the slag sand machines directly into

bricks, and this being accomplished, success was assured.

In designing this machine, the following points had to be kept in view, viz., great depth of moulds, because the slag sand is very spongy and compressible; an arrangement by which the water could escape from the moulds without blowing the bricks to pieces; great pressure, in order to consolidate the sand in the mould; safety against over pressure, in case too much or too hard a material should get into the moulds; and great care in mixing the lime with the slag sand in fixed proportions, as well as great regularity in filling the moulds.

These requirements are fully met by the brick press which I shall now describe, and which is, in my opinion, one of the safest and most powerful mechanical brick presses ever made. The pressure is given by two cast steel cams, which are fixed upon a forged steel shaft  $7\frac{1}{2}$  inches in diameter. This shaft, resting on bearings between two strong frames, is put in motion by very powerful double-gearled spur wheels, the first motion shaft having a fly-wheel upon it to steady and equalize the pull upon the strap. The pressure cams act against rollers fixed upon two steel cylinders or rams. These rams transmit the pressure to the moulds in a table. The table is circular, and contains six pairs of moulds, so that four bricks are pressed at one time, the table remaining stationary during the operation. At the same time the bricks are being pressed, two other pairs of moulds are being filled up with material—whilst the other two pairs are delivering up the four bricks pressed at the previous revolution of the cam shaft. The bricks are pushed out of the mould by smaller pistons acted upon by separate cams.

The moulds are lined with changeable steel plates  $\frac{3}{16}$  inch thick, and the sand and lime is fed into them by two pug mills. These pug mills are fitted with six knives each, so as the more thoroughly to mix and chop the spongy slag along with the lime. The table is shifted round by a kind of ratchet motion, also worked by a cam on the outside of the framework, and acting upon the weight bar and levers.

Immediately above the pressure cylinders are two pressure stops, which are

held down by the heavy-weighted levers. These levers, therefore, receive the whole pressure put upon the bricks, and in case there should be too much sand getting into the moulds they simply lift up and relieve the strain. The weights can be weighed at option, and thus form an exact gauge of the pressure upon the bricks. The moulds are generally filled so as just to lift the levers in ordinary work. The filling is easily regulated by the set of the knives on the pug shafts, which press the material into the moulds, and one side of the pug mill cylinder is made to open so that the knives are accessible at any moment.

The pug mills are filled by means of the measuring and mixing apparatus placed on the floor immediately above the brick press.

The mixing and measuring apparatus is very simple and efficient, and works without any trouble. The slag sand is tipped into a hopper by large barrows, which are lifted up by a hoist. At the bottom of this hopper there is a revolving cylinder, with ribs cast upon it, which, revolving under the hopper, carries a certain thickness of sand, the thickness having been previously regulated to the requirements of the press.

The slag then falls upon a sieve, which separates any large pieces of slag in a solid state, and at the same time allows the falling sand through the sieve to fall like a shower. The lime is fed into a separate hopper, and is regulated very much like the feed of corn into millstones. The lime then passes down a shoot, which forms part of the slag sand sieve, where it meets the shower of sand—falling together with it—thus getting thoroughly mixed. As before stated, this lime is selenitic lime, and is prepared upon the works.

The bricks, when taken from the brick press, are placed upon spring barrows, holding fifty each. They are then taken and stacked in sheds, where they are allowed to remain about five or six days, after which they are simply stacked outside in the weather to harden. The percentage of loss is very little, not amounting to two or three per cent. In fact, when once the bricks are upon the barrows, there is little or no waste.

Each machine is capable of turning out about 10,000 bricks per day, and,

since starting, we have sold about 4,000,000. Large quantities are shipped to London at a cost of 17s. to 18s. per 1,000 for freight; in other words, about 10,000 tons of slag sand has been consumed for this purpose alone. The following are a few of the advantages of these concrete slag sand bricks, viz.:—Being pressed, they are perfectly uniform in size and thickness; they are much cheaper than ordinary red bricks, compared in weight with which they will weigh one ton per thousand less, then there is this further advantage that there are no wasters or halves. For inside work there is a great saving both in bricklaying and mortar, more especially when plastering; the walls being of a uniform thickness; and the bricklayers like them, because they can do more work with less labor, the bricklayer's laborer finding he has a ton per thousand less to carry, as well as considerably less mortar. Another remarkable property of the slag bricks is that the joiners can drive nails directly into them without splitting, and thus, for skirting and door-work, they are saved much trouble in plugging the walls; and, finally, the longer the bricks are kept the harder they get.

I can now confidently say that for many months past we have been steadily working away at the various products mentioned in this paper, and that with the exception of a little outlay for the purpose of increasing our output, we have laid out no money upon experiments or works.

The task, however, has been a severe one. When I designed the mill, I brought to my assistance some of the most experienced millwrights in England—men accustomed to machinery for manipulating hard and gritty substances; and yet there is scarcely a piece of machinery on the works, with the exception of the engine and shafting, that has not either been abandoned, redesigned, or rebuilt, in order to adapt the machines to this peculiar material, the extraordinary cutting nature of which seems to destroy everything with which it came into contact. In proof of this, I may mention two facts, viz., that in six hours' working, the fields and furrows in a pair of French burr millstones, intended for Portland cement grinding, were com-

pletely obliterated, whilst the hardest steel bars in a Carr's disintegrator were cut completely through after six or eight days constant running.

The position of an engineer and an inventor under these circumstances—standing as he does between failing machinery and the angry directors of a limited company, in times like these—is one which has only to be experienced to be thoroughly appreciated; but, thanks to Messrs. Gilkes, Wilson, Peace, & Co., and to one or two practical men among the directors, I have been enabled, through their aid and confidence, to carry the thing to a successful issue.

In addition to the works and progress made by myself at the Tees Iron Works and the Cleveland Slag Working Company's Works, I must not forget the labor and success obtained by my friend Mr. Henry Hobson, engineer at the Moss Bay Iron Works, Cumberland. Mr. Hobson has taken a path different, as far as I know, to any of his predecessors, inasmuch as in making bricks he first of all pulverises the solid slag, and uses no lime whatever. By this system the slag is taken from the solid slag balls, made from hematite Bessemer iron, and broken into pieces sufficiently small to pass under very massive edge runners, where it is ground or crushed by the sheer weight of the runners into small dusty shingle. It is then passed by elevators into French burr millstones, and ground into powder.

From the stones it passes directly into the brick press without any admixture of lime or any other aid except that of being well damped with water before pressing. This brick press also has a rotary table, and the material is fed into the moulds recessed therein by hand. The pressure given from above by a self-acting cam, put in action by the continuous rotary motion of the table; the bricks come out well pressed and are of excellent shape, and there appears to be no doubt about the quality. At the same time, they have a great many wasters. The bricks are very heavy, and the cost of grinding the slag entails a heavy and expressive plant, with, I fear, a large amount of wear and tear. The large amount of lime in the slag made while producing Bessemer iron seems to be sufficient, when treated in this way, to

reunite the pulverized slag and to "set" in a most remarkable manner. I can only account for this setting property by supposing that the slag, when pulverized in the dry state in which it comes from the furnace, takes up a large amount of water, and forms a hydrated compound of silicate of lime and alumina, and thus reunites the mass in the same way as Portland or Roman cement.\* On the other hand, this excess of lime is often very dangerous, as the slag, after exposure to the air or an excess of moisture, often swells and falls into powder, and bricks made from it are liable to fall to pieces. This, however, is not the case with Cleveland slag, nor, I think, with any except with that made from hematite ore with an excess of lime.

The next process in successful operation is that known as Woodward's, and, although a revival of a very old method, I must certainly give that gentleman, and those who have worked the thing out at the furnaces, a great deal of credit for their perseverance, and for the success at which they have arrived. I must also, in all honesty to them, say that most of their manufactured articles are of a very serviceable nature. They are, however, employed for footpaths, roads, &c., being totally unfit for building purposes. As at present worked, the process is not at all complicated, but only certain qualities of slag are suitable, and at times when the furnaces are "changing" the number of wasters is enormous, while the works have sometimes to be stopped for days. The slag is run direct from the furnaces into moulds ranged round the outside of a large rotary table. The machine or table remains stationary whilst each separate mould is being filled, the table is moved by hand, thus constantly presenting empty moulds to the stream of molten slag. As soon as the slag becomes set in the moulds a catch is knocked away, and the bottom of the mould drops down upon a hinge and the brick or block falls out. It is then taken into annealing ovens, where the temperature is raised to nearly a white heat, after which it is allowed to cool. The high price obtained in the market for these goods enables the company to meet their expenses, but, I be-

lieve up to the present time they have not done more than this. The goods they produce are very hard, uniform in size, and look well when laid; but they are liable to crack, particularly in winter, and, as before mentioned, there are many objections to their ever being employed as building material.

At the Leeds meeting of this institute last year, Mr. Bashley Britten introduced to your notice his novel system of making glass from blast furnace slag. Mr. Britten, it will be remembered, proposed to take the molten slag in a ladle from the blast furnace and to pour it into a Siemens furnace, where certain additions of carbonate of soda and silica are added according to the quality of the slag used and the glass to be produced.

I am very glad to learn from Mr. Britten that the extensive experiments which have been carried on during the year have proved perfectly successful, and that, under the title of "Britten's Patent Glass Company," for which Mr. Herbert Canning is the secretary, large works are being built at Finedon, in Northamptonshire, where in a few months they will be ready to manufacture large quantities of glass bottles. These bottles on the tables are made entirely by this process.

I have now only one more product from slag to mention. It is that of slag wool, or, as it is sometimes called silicate cotton, from its great resemblance to cotton wool. The manufacture of slag wool has often been attempted in England, but I believe only with partial success.

I have, however, learned from Mr. Edward Williams that many years ago Mr. Edward Parry made a large quantity of it in Wales, although that, in consequence of the injurious effect upon the men, it had to be abandoned. The manufacture is now carried on at the Tees Iron Works, and I can safely assert, without the slightest inconvenience, either to the men in the yard, or even to the man who makes it.

The process is extremely simple. A jet of steam is made to strike upon the stream of molten slag as it falls from the usual runner into the slag bogies or wagons. This jet scatters the molten slag into shot, and as each shot leaves the stream it carries a fine thread or tail with it; the shot, being heavy, drops into the ground, whilst the fine woolly fibre is

\* I have given an analysis of an average sample of Bessemer and Cleveland slag at the end of my paper for reference.

sucked into a large tube and discharged into a chamber. This chamber is very large, and is covered with fine wire netting or sieve wire. The steam and air carry the woolly particles all over the chamber—the finest into recesses formed for the purpose; the heavier into the body of the chamber. After each blowing it is selected and taken up with forks and put into large casks or bags for shipment or otherwise. The inside of the chamber represents a most remarkable and curious spectacle after each blowing.

The wool, as will be seen by the samples on the table, is of a snowy-white appearance. Slag wool, or silicate cotton, is chiefly employed to cover steam boilers, pipes, &c. Messrs. Jones, Dade & Co., of London, are the sole agents for its sale, and they have taken out one or two patents for its application. The most noteworthy of these is for what they term mattresses, some of which they have kindly forwarded for inspection. These are about 2 ft. to 3 ft. long, and 1 ft. wide, by 2½ in. thick. The mattresses are laid upon the boiler or pipes to be covered, and are secured in the usual way. Its perfect incombustibility, combined with its non-conducting and indestructible properties, give this material many advantages over any other for this class of work.

*Table showing the various Forms into which Blast Furnace Slag is being made, and to what Purpose it is being Applied.*

*Slag Sand.*—This is employed for

making concrete, building bricks, mortar, and cement; for agricultural purposes and gardening.

*Slag Shingle* is being used largely for concrete, and for roads and footpaths.

*Slag Wool.*—For covering steam boilers, steam pipes, hot-water pipes, fire-proof rooms, ice-houses, cisterns, gas and water pipes, as a protection against fire, as well as for filtering chemicals.

*Paving Blocks.*—Employed for streets and footpaths, stables, coach-house yards, crossings, breweries, and for kerbstones and channelling.

*Building Bricks.*—Made by pulverizing the solid slag and then pressing the bricks in a press.

*Glass*, by Mr. Bashley Britten's patent process, into roofing glass, bottles, guage glasses, and many other articles too numerous to mention, for which a pure glass is not absolutely essential.

*Analysis of Blast Furnace Slag.*

	Cleveland. Per cent.	Bessemer. Per cent.
Silica.....	36.50 ..	35.00
Alumina.....	22.95 ..	15.00
Lime.....	32.68 ..	46.40
Magnesia.....	5.83 ..	2.00
Protoxide of iron.....	0.06 ..	0.10
“ manganese ..	0.32 ..	0.10
Potash.....	0.59 ..	0.40
Soda.....	0.37 ..	0.20
Sulphur.....	1.74 ..	1.50
Phosphoric acid.....	nil. ..	nil.
Less oxygen of sulphur.	101.04 ..	100.70
Combined with lime...	0.87 ..	0.75
Total.....	100.17 ..	99.95

## ON SCIENTIFIC METHOD.

By M. M. PATTISON MUIR, F.R.S.E.

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WHETHER we turn our attention on ourselves, or seek to pursue the study of mankind in general, or, on the other hand, confine our view to the natural world around us, there is in each case one method by pursuing which we arrive at exact knowledge: that method is the Scientific. What, then, is Science, and what the scientific method? The question, What is Science? is synonymous

with another, What is Knowledge? Here is a stone: how do I know it to be a stone? Because it is *like* so many other things which I call stones; it is hard, it possesses a certain color, it is not easily broken, and so on. I know that it is a stone because I recognise in it certain qualities which I have grouped together and regarded as characteristic of those pieces of matter, to all of which

I therefore apply one general name, viz., *stone*. In stones, therefore, there is some quality, or qualities, possessed by all in common, such qualities being sufficient to mark off the possessors of them from all other kinds of matter. Yet these stones may differ from one another in many other ways.

Such a classification is a scientific one. I *know* something about these stones. Were there only one piece of stone in the world I could never know anything about it as a stone. To know we must compare; and the scientific method consists in finding unity amid variety, in tracing the inner relationships between seemingly diverse things (or thoughts), in finding the common link which binds together those things at first sight appearing so widely separated.

This, then, is the aim of Science—to know. And to attain this aim she must find the agreements and differences between all things; in other words, she must classify. When we have arrived at a complete system of classification of all phenomena we shall have attained the purely scientific aim of our intellectual existence.

To awaken consciousness there must be more than one phenomenon. Object is compared and contrasted with object, and hereby resemblances and differences are discovered: these are retained in the memory, and compared with other resemblances and differences, as these may be discovered, until at last we are able to find identity amid diversity, to group together a number of objects by means of some great common property, and from this identity to draw inferences which rest on some point of resemblance, and which have for their basis the law that "that which is true of one thing is true of its equivalent." We gradually leave behind us the old idea that ceaseless change is the order of all things; we learn to believe that what we to-day know as Iron will yet be Iron a thousand years hence; we get something definite to reason on, and, step by step, the varied and strange phenomena of Nature are found to be lawful phenomena—are found to have a fixed basis underlying them; until at last we arrive at a general expression for so many and so varied phenomena that we give it the name of a *law of Nature*. Thus we rise from

the trivial to the abiding, from the changing to the changeless, from the passing to that which endures, and from that which was capricious to that which is governed by law.

But even here, even in these *natural laws* we have not attained absolute certainty; they are but general expressions, including a vast number of else isolated phenomena. But what is beyond these phenomena? What is the cause of all these causes? Science, strictly so-called, gives no reply.

It may be urged that modern science teaches that all things are in a continual state of change; that there is no such thing as rest in the physical universe; that every form of energy is but the expression of a change of material particles: but Science, we answer, has gained this knowledge only by grasping the changeless facts underlying the changing phenomena. We do not now simply know that the material universe is constantly undergoing change: we are able, to some extent, to follow the steps of this change; we have reduced the very mutability of Nature to law; we have compared change with change, and in some instances have succeeded in detecting the connecting-link. We have made a beginning in the classification of the changes of Nature.

If the aim of Science be to detect identity amid variety, it is asked—What means does she employ for accomplishing this end? *Observation, Experiment, and Inference.*

From repeated observations we discover an identity; from a number of identities we infer that what is true of one is true of another; from a number of combined inferences we draw a wider inference, which again we generalize into what is called a law. But before we can establish a law we must make use of the process of deduction—if such or such an inference be true, then this or that phenomenon must follow. Observation or experiment tells us whether the phenomenon does occur or not; if it does, another proof of the correctness of the law is gained; if it does not, there is the less probability that the so-called law is a true one. Thus it is from a series of partial hypotheses which generalize a number of facts that we at last ascend to the hypothesis which shall in-

clude in its expression all the isolated facts—that is, to a general law. And this method of combined observation, experiment, induction, and deduction is the Scientific Method.

There is nothing peculiar in this method; it is but common sense reduced to rule. We are continually and unconsciously guided by the scientific method in our every-day conduct. The countryman who, in the morning, assures his neighbor that it will rain before midday, bases his assurance upon a train of scientific reasoning; he has repeatedly observed that certain appearances of sky, a certain direction of wind, and rain, are associated together: from these observations he has, probably unconsciously, framed the hypothesis that the three sets of phenomena are related together in such a manner that, given the two first, the third is sure to follow; he has proved the value of his hypothesis again and again, by acting on it,—the only scientific method of proving an hypothesis,—and he at last has come to regard it as a law of Nature. But after all it is only an hypothesis, probably a very partial one, and Nature will very likely some day teach him that he has been too ready to narrow her working to the sphere of his own capacities.

The scientific method is applicable, more or less, to all branches of phenomena coming within the scope of human understanding. But the domain claimed by Science is so great as to make it impossible for any man, or body of men, to examine it with completeness. Hence arises the necessity for divisions and subdivisions in Science. The first part which must be examined is, clearly, the laws which regulate reason itself, the laws of thought, and their application to the processes of inference. The study of these belongs to the Science of Logic. The application of these principles to reasoning about numbers and quantities constitutes the Science of Mathematics, and so on.

We have one set of sciences dealing with physical or material objects; another with mental, moral, or immaterial objects; or with these as they are modified by social relationships. Hence arise the two broad classes of natural or material, and mental or moral science. The scientific method is applicable to both

alike, only the questions arising under the second division are more complicated and much more difficult of solution than those under the first. Indeed it is only within recent years that the scientific method has been, in any great degree, applied to the questions of mental and social phenomena.

In endeavoring to classify scientifically the phenomena of Nature we make use of the method, first of all, of Observation.

From experience we gather together a number of facts, but in order to classify these facts we need often have recourse to Experiment.

In the first-named process we do not alter the conditions under which phenomena occur in Nature; we *merely observe* these phenomena as they are presented to us, or at most we *vary our point of view*. In carrying out an experiment, on the other hand, we must carefully vary the *conditions of the phenomenon*, and endeavor, as far as possible, to exclude those which have no influence upon the fact we are studying.

Observation and experiment are the first steps in the ladder leading upward to scientific knowledge.

But where are observations to begin? In our world facts are so numerous, phenomena so almost infinite in number, that no man can say which are to be observed and which neglected. Hence we find that many of the greatest scientific discoveries have taken their rise from what we call "chance" observations. But that which is passed by, by one man, as altogether unimportant, in the hands of another leads to the most important results. The twitching of the leg of a dead frog when accidentally touched by the wires coming from a battery caught the eye of Galvani, and he, following up this chance observation, so added new facts and new theories to our scientific stock that one of the greatest branches of Electric Science now derives its name from this man.

It is impossible, however, to carry out the method of observation beyond certain limits. Our powers of hearing are not delicate enough to perceive vibrations exceeding somewhere about 38,000 per second; hence if there be sound-producing vibrations quicker than these no amount of observation will enable us to

detect them. Not only is this method unable to pass beyond somewhat narrow limits,—it is also liable to lead us to untrue conclusions, unless it be very carefully used. Do we not often hear it said—"See how the buildings of our great ancestors have lasted during the centuries,—strong and firm these old temples, or walls, or roads remain to this day, while the structure which we have raised to-day by to-morrow begins to decay?" Observation tells us that the older buildings remain; observation tells us that the newer quickly disappear; but observation does not tell us that it is only the great buildings of antiquity which remain—the buildings which, from their purpose and design, we should expect to be *very* strongly put together; and that the ordinary houses and the common buildings have all *long ago* utterly disappeared. The conclusion drawn from observation alone—viz., that our ancestors built more strongly than we do—is therefore a conclusion which is not proved by the evidence adduced.

Again, the mind of the observer may be so overcast with prejudice or fancy, or may be so dim and dull as either not to receive aright the image of outward things, or to transpose that image so that it becomes a caricature, not a truthful picture. He who when shown, in the old heathen temple, the picture of all those who had been saved from shipwreck after paying their vows, and asked to believe *now* in the power of the gods, replied "But where are they who paid their vows and were not saved from shipwreck?" was a man whom we have often need to copy.

By *observation alone* we cannot tell the *exact* conditions regulating the occurrence of any phenomena; these conditions can be determined only by *experiment*. But where an observation has been made, and we are wishful to determine the exact conditions which regulate the occurrence of the observed fact, we shall find that it is very difficult to fix on these conditions. Every fact is so closely related to so many others that it becomes very hard to strike out those conditions which are really non-essential. Nay, it often happens that what at first sight appears to be the most important condition of a phenomenon

proves, after experiment, to have little or no influence on this phenomenon while other overlooked circumstances are the true governing causes. Thus if we let fall a piece of lead and a sheet of paper of the same weight, from a height, we find that the lead reaches the ground long before the paper does. We should naturally conclude—as all, or almost all men did before the time of Galileo—that the *nature* of the two bodies influences the velocity of their descent; whereas it is actually found, by carefully conducted experiments, that no property of bodies except their absolute mass has any influence upon their gravitating powers. In experiment we must therefore seek to eliminate, one by one, those circumstances which are really not of importance as influencing the phenomenon in question; we must simplify the experiment as far as possible, taking care, however, that in our attempts at simplification we do not overlook *the* circumstance really governing the phenomenon. After all, however, some overlooked condition may be present, the non observance of which entirely vitiates our results. Experiments were long ago very carefully carried out with a view to prove that earth can be formed from water; water was again and again distilled from a perfectly clean glass vessel, yet there remained a small quantity of a white earth in the vessel in which the water was distilled. If the water has not been converted into the white earth, where has this substance come from? The conclusion seemed inevitable, and the conclusion was therefore adopted—water may be converted into earth. But the overlooked circumstance was this:—Water acts on glass, especially at high temperatures, so as to dissolve part of it, and the white earth is really a portion of the glass vessel dissolved by the boiling water, and left in the vessel when the water has been entirely boiled away.

An exceedingly instructive example of the process of elimination of non-important conditions of experiment is afforded by Sir Humphrey Davy's researches upon the electrolysis of water. When water was decomposed by the electric current, an acid and an alkali invariably made their appearance at the poles along with the oxygen and hydrogen. Electricity, some people supposed,

caused the production of the acid and the alkali; others imagined that water always contains acid and alkali. By using agate or gold vessels in place of glass, to contain the water, Davy showed that less acid and less alkali was produced. Finally, by carrying out the decomposition in gold vessels, in the exhausted bell-jar of an air-pump, he was able to obtain from pure water, oxygen and hydrogen free from both acid and alkali, thus showing that the presence of air was in some way the cause of the production of the acid and of the alkali.

If, therefore, an experiment seems to point irresistibly to this or that conclusion, we must be very chary in accepting this result until we have again and again varied the conditions of the experiment, so as to bring under notice every circumstance which can in any way influence the phenomenon we are investigating.

To discover what condition may or may not influence a given phenomenon becomes therefore one of the most important problems of the scientific investigator. And here the man of a keen insight and quick apprehension has a very great—in fact, an immeasurable—advantage over the ordinary dull and plodding experimenter.

There seems to be a somewhat widespread idea that there is no longer any use for genius; that magnificent laboratories, elaborate organization, Government endowment, and certificated teachers are to carry all before them, and achieve results such as the world has never seen. To me it seems that now, as ever, genius is necessary for any really great discoveries; that no amount of training, nor of organisation, nor of artificial selection, can make up for the absence of native talent—of that subtle, scarce definable something, which we call genius.

If the genius is there, by all means let us educate it as best we may; let us also do our utmost to train all, whether possessed of genius or not,—for in doing this we shall, at any rate, be giving to all the means of leading a nobler and a more useful life than they otherwise could; but let us beware of thinking that *we* can evoke this rare and wonderful product, genius, by any method of selection, or by any system of competitive examina-

tion: plodding, persevering, patient work is of the very utmost importance; but the power of grasping the one true condition of a problem, to the exclusion of the many trivial but *seemingly* important conditions, is of yet more importance; while he who combines both of these qualities,—he who has genius to see and patience to follow,—he it is who stands forth as the great discoverer, as the poet of Science. The successful investigator of Nature must be patient; he must very often reserve his judgment until experiment proves to him that this or that conclusion must be the right one; he must be ready to frame hypotheses, but he must not shrink from submitting these to the most rigorous experimental test, and when he finds experiment and hypothesis opposed he must be ready to doubt the latter, but yet not despair of finding another truer generalization; he must never disdain help, even from the humblest; he must have no envy; he must neglect no objection; he must not choose and *then* compare, but after comparing many times he must choose; and while he is thus humble he must not hesitate to frame hypotheses,—he must risk something in his search for truth, knowing that in rigorous experiment he has a means of trying his queries whether they be true or not. "The philosopher," says Faraday, "should be a man willing to listen to every suggestion, but determined to judge for himself. He should not be biassed by appearances; have no favorite hypothesis; be of no school; and in doctrine have no master. He should not be a respecter of persons, but of things. Truth should be his primary object. If to these qualities be added industry, he may indeed hope to walk within the veil of the temple of Nature.

I have said that we still need men of genius who can see through the tangled web of facts and catch a glimpse of the governing power behind. But it may be asked, Is not this a different method from that of strictly inductive reasoning recommended by the great father of true logic, Bacon himself? Yes, it is somewhat different; yet I think that a due attention to historical facts will show us that without deductive reasoning no true generalizations have ever been reached in Science.

By an examination of facts alone we

gain empirical knowledge; scientific unity can only be gained by embracing these facts within one general principle. A mere collection of empirical facts does not constitute scientific knowledge; we must explain these facts,—that is, we must take out the folds, “*Ex plicis plana redere*,” we must show the resemblances, more or less deep, between the facts; so long as a fact remains alone, unattached and seemingly unattachable to any other, we feel a certain uneasiness, unsatisfiedness, in regarding this fact; and such an uneasiness *may have*—in certain ages *has*—developed into a superstitious dread of the unexplained fact. In other ages than the present the sweep of the comet across the sky was regarded as an omen of evil,—it was an awful unexplained fact,—but now that we know that the laws governing the movements of the comets are the same as those which rule the calm and peaceful stars, we no longer experience any dread at the approach of these, once fearful, visitors. But the man of Science is often taunted with his lack of awe and reverence of the mysteries of Nature: the accusation is, I believe, only made—if made in earnest—by those who cannot take the trouble of investigating Nature for themselves; by those who think it a grander thing to speak of mystery, and greatness, and reverence, than to exhibit those qualities in themselves which they demand in others. To quote the words of Charles Kingsley:—“There is a scientific reverence, a reverence of courage, which is surely one of the highest forms of reverence, that, namely, which so reveres every fact that it dare not overlook or falsify it, seem it never so minute; which feels that because it is a fact it cannot be minute, cannot be unimportant; . . . and which, therefore, just because it stands in solemn awe of such paltry facts as the Scolopax feather in a snipe’s pinion, or the jagged leaves which appear capriciously in certain honeysuckles, believes that there is likely to be some deep and wide secret underlying them which is worth years of thought to solve. But as for that other reverence which shuts its eyes and ears in pious awe . . . what is it but cowardice, very pitiable when unmasked; and what is its child but ignorance, as pitiable, which would be ludicrous were it not so injurious?”

To return to the main subject. We wish for hypotheses which shall explain our observed or experimentally determined facts. If we are determined to do without hypotheses in our scientific method, let us see what is required of us. Given two circumstances, and one hundred other distinct circumstances which may possibly be connected with these, we are required to find, by mere inductive reasoning, the law regulating the coincidences existing between these circumstances. Now there are no less than 4950 pairs of circumstances, under the conditions just named, between which a coincidence may exist. We shall therefore be required to try these 4950 cases, in order to determine which of them represents the true grouping of the connected circumstances. Would it not be easier, after attentively looking at all the circumstances, to say, probably the coincidence lies here, and then try whether it does or not?

As an illustration of the vast number of combinations possible under certain circumstances the following is instructive:—In whist, four hands of thirteen cards each are simultaneously held: “The number of distinct possible deals is so great that twenty-eight figures are required to express them. If the whole population of the world—say a hundred thousand million persons—were to deal cards day and night for one hundred million years, they would not have exhausted in this time one one-hundred-thousandth part of the possible deals.” If we do not know anything of hypotheses, do not hazard at the least a guess, we shall very probably find ourselves—like the alchemists—spending our years in useful labor, searching in the labyrinth of detached facts without any guide, and, like them, we shall arrive at no true results.

The doctrine or theory of combinations enables us to determine the possible number of ways in which a given set of facts or circumstances may be grouped together. This theory is of the utmost importance in enabling us to form just conceptions of the nature of the task set before him who would investigate Nature. The importance of the doctrine of combinations is thus insisted on by James Bernoulli:—“It is easy to perceive that the prodigious variety which

appears both in the works of Nature and in the actions of man, and which constitutes the greatest part of the beauty of the Universe, is owing to the multitude of different ways in which its several parts are mixed with, or placed near, each other. But because the number of causes that concur in producing a given event, or effect, is oftentimes so immensely great, and the causes themselves are so different one from another, that it is extremely difficult to reckon up all the different ways in which they may be arranged or combined together. It often happens that men, even of the best understandings and greatest circumspection, are guilty of that fault in reasoning which the writers on logic call *the insufficient or imperfect enumeration of parts or cases*; insomuch that I will venture to assert that this is the chief and almost the only source of the vast number of erroneous opinions—and these, too, very often in matters of great importance which we are apt to form on all the subjects we reflect upon, whether they relate to the knowledge of Nature, or the merits and motives of human actions. It must therefore be acknowledged that that art which affords a cure to this weakness or defect of our understandings, and teaches us to enumerate all the possible ways in which a given number of things may be mixed and combined together, and that we may be certain that we have not omitted any one arrangement of them that can lead to the object of our enquiry, deserves to be considered as most eminently useful and worthy of our highest esteem and attention. And this is the business of the *art or doctrine of combinations*. Nor is this art or doctrine to be considered merely a branch of the mathematical sciences, for it has a relation to almost every species of useful knowledge that the mind of man can be employed upon. It proceeds, indeed, upon mathematical principles in calculating the number of the combinations of the things proposed; but by the conclusions that are obtained by it the sagacity of the natural philosopher, the exactness of the historian, the skill and the judgment of the physician, and the prudence and foresight of the politician may be assisted, because the business of all these important professions is but to form reasonable conject-

ures concerning the several objects which engage their attention, and all wise conjectures are the results of a just and careful examination of the several different effects that may possibly arise from the causes that are capable of producing them."

When we apply this theory to facts we are astonished at the results. Speaking of "the variety of logical relations which may exist between a certain number of terms," Prof. W. Stanley Jevons says:—"Four terms give 16 combinations, and no less than 65,536 possible selections from these combinations; . . . for six terms the corresponding numbers are 64 and 18,446,744,073,709,551,616. Considering that it is the most common thing in the world to use an argument involving six objects or terms, it may excite some surprise that the complete investigation of the relations in which six such terms may stand to each other should involve an almost inconceivable number of cases. Yet those numbers of possible logical relations belong only to the second order of combinations."

If the facts of Nature be so numerous we can never hope to know them all. Perfect knowledge is for us impossible: how, then, are we to make the most of that partial knowledge which we can alone attain to? How can we measure the extent of our knowledge of any subject? By means of the theory of probability.

Although perfect knowledge is impossible, yet we cannot be content with the accumulation of mere isolated facts. We attempt to group facts together, to form theories, and to apply these to the explanation of newly discovered facts. The theory of probability must guide the mind in gauging its knowledge of any group of facts. And the theory of probability is, as Laplace has said, "good sense reduced to calculation."

Suppose it be required to determine the atomic weight of an element, we devise various methods of measurement, we repeat the measurements again and again, but there are nevertheless errors inherent in each method, errors in the instruments employed, and errors in our readings of these instruments, &c. The result can never be more than approximately correct, and the results obtained by the different methods will not be exactly the same. We do not therefore

know the true atomic weight of the element; but the theory of probability enables us to assign to each result its comparative trustworthiness, and so to deduce the numerical probability of the average result being absolutely correct.

The application of the theory becomes often very difficult. Our knowledge is at the best so limited that it is difficult to assign to two propositions their relative probabilities. When we deal with simple numbers, as those obtained in the illustration given, we can apply the theory with comparative ease; but when we come to more complicated questions in physical science we find it almost impossible to obtain sufficient, and sufficiently reliable, data to enable us to estimate probabilities. But, as Prof. Jevons has pointed out, "Nothing is more requisite than to distinguish carefully between the truth of a theory and the truthful application of the theory to actual circumstances. As a general rule, events in Nature or Art will present a complexity of relations exceeding our powers of treatment. The infinitely intricate action of the mind often intervenes, and renders complete analysis hopeless. If, for instance, the probability that a marksman shall hit the target in a single shot be 1 in 10, we might seem to have no difficulty in calculating the probability of any succession of hits: thus the probability of three successive hits would be one in a thousand. But, in reality, the confidence and experience derived from the first successful shot would render a second success more probable. The events are not really independent, and there would generally be a far greater preponderance of runs of apparent luck than a simple calculation of probabilities could account for. In many persons, however, a remarkable series of successes will produce a degree of excitement rendering continued success almost impossible."

We must be content with partial knowledge.

In ascending from facts to generalizations, which generalizations are more or less probably true, we must make use of hypotheses; we must accumulate facts, make an hypothesis to explain them, and test the hypothesis by appeal to facts.

The investigator of Science must begin with facts; he must end with facts; but

between the two he must interpolate hypothesis. He looks at a number of facts; gradually he sees, or thinks he sees, a light dawning on him—a central idea, round which all the facts group themselves in a luminous whole. But he does not stop here; he again appeals to facts. He says "If my hypothesis be correct, this or that fact must follow." Then he tries experiment. Is the predicted fact really a fact? By the test of experiment he is content to abide; he knows that Nature—however hard sometimes it is to make her answer at all—never answers except truly.

Hypotheses must be used in Science, but hypotheses may be abused. What, then, are the marks of a good hypothesis?

An hypothesis must be workable; it must not go against any well-established scientific generalization, and it must be ready to submit to have its predictions proved by strictly experimental methods.

A good scientific hypothesis must be workable; that is, it must allow us to make determinate predictions—predictions which can be proved or disproved by experiment. A vague generalization, which does not allow of definite deductive reasoning, can have no place as a scientific hypothesis.

A good scientific hypothesis must not be opposed to any well-established generalization of Science. This statement may probably be called in question by many. It is no uncommon thing to find people talking of the way in which Science sweeps aside all preconceived ideas, all Old World notions, all long-cherished delusions. And this is very true; only these people, I am afraid, forget the other side of the case; they forget that did Science present us with nothing but change succeeding change, doctrines swept away and replaced by others to be themselves removed as Science advances, Science would have no claim on our acceptance. It is because Science is at once prolific of changes, and conservative in the extreme, that she has accomplished her work in the world.

We know so little of Nature that we must be ready at any moment to give up that which we had supposed we did know; and yet we have such trust in the stability of Nature that we must cling to those theories which have been gained

by slow accumulation of facts, until there is absolute experimental proof of their falsity.

Such a theory as that of the Conservation of Energy is the general expression of a vast number of facts: it explains these facts; it is a well-established generalization of Science. If we are seeking to explain a number of newly-discovered facts, it is evidently our duty to frame an hypothesis which shall not be itself out of keeping with this theory of the conservation of energy. For if we do not do so we are very probably assuming the incorrectness of that great body of facts upon which the theory rests. It would in most cases be almost better to distrust our personally-observed facts than to distrust so well-founded a generalization. This is one view to take of the question. But, on the other hand, the theory of the conservation of energy is a theory only: it is probably true; we do not, and cannot, know whether it is or is not certainly true. If the observed facts, after the most careful observations, still remain unmoved, and if they are apparently opposed to the generally-accepted theory, the better method will doubtless be complete reservation of judgment until further experimental data is forthcoming. If the observed facts are, however, absolutely opposed to the theory, and if these facts cannot be gainsaid, then the theory must go; it has done its work, and must be supplanted by a wider generalization. The scientific investigator must therefore cling to theory, and yet be ready to abandon theory at the call of fact.

It is, it seems to me, of the utmost importance to insist on this view of the work of the student of Nature; to declare that he trusts Nature altogether, but he distrusts his own powers of comprehending the workings of Nature; that he feels that all things are changing, but he nevertheless clings to what he can grasp of the changeless. The frame of mind of the man of Science is, then, at once opposed to those who would have us believe that "victorious analysis" has now at last reduced all things under her feet, and to those who would have us accept the teaching of authority in place of the teaching of facts. Both alike assume a vast amount of knowledge which neither is possessed of. But the

last characteristic of a good scientific hypothesis is its readiness to submit to have its predictions proved by strictly experimental methods. Every newly-discovered fact which is capable of explanation in terms of an accepted hypothesis adds something to the *probable* truth of that hypothesis. Every newly-discovered fact which cannot be explained in terms of the hypothesis takes away something from the probable truth of the hypothesis. We may observe facts which are apparently opposed to the hypothesis which we have provisionally accepted, and yet we may not be justified in condemning the hypothesis, because these facts may either be but partially examined by us, or the hypothesis may not have been fully grasped in all its bearings. But if the hypothesis is to hold its ground there must be no experimentally demonstrated fact, the existence of which would be impossible were the hypothesis correct. To take an instance:—The upholders of the Phlogistic theory affirmed that when a metal is burned it parts with phlogiston; that the product of combustion is metal *minus* phlogiston; and that the re-transformation of the product of combustion into metal is brought about by the absorption of phlogiston. The upholders of what might be called the Oxygen theory affirmed that when a metal is burned it combines with oxygen; that the product of combustion is metal *plus* oxygen; and that the re transformation of the product of combustion into metal is brought about by the removal of oxygen. Each hypothesis had facts in its favor; each explained many facts. But the fact discovered by Davy, in 1807, that the metals potassium and sodium are actually produced by the removal of oxygen from those substances which are themselves formed when these metals are burned, could *not* be explained in terms of the phlogistic theory. Either the fact or the theory must give way. The fact was established beyond a doubt; therefore the theory—in its then accepted form at any rate—had to succumb.

A good scientific hypothesis must, then, be in keeping with facts; but it does not follow that it must be simple, or that it must make no claims upon our belief. The hypothesis which well explains the facts concerning light is, we

might almost say, absurd in the demands which it makes upon our credulity. "We are asked by physical philosophers to give up all our ordinary prepossessions, and believe that the interstellar space which seemed so empty is not empty at all, but filled with *something* more solid and elastic than steel. As Dr. Young remarked, 'the luminiferous ether pervading all space, and penetrating almost all substances, is not only highly elastic, but absolutely solid.' Sir John Herschel has calculated the amount of force which may be supposed, according to the undulatory theory of light, to be exerted at each point in space, and finds it to be 1,148,000,000,000 times the elastic force of ordinary air at the earth's surface, so that the pressure of the ether upon a square inch of surface must be about seventeen billions of pounds. Yet we live and move without appreciable resistance through this medium, indefinitely harder and more elastic than adamant. All our ordinary notions must be laid aside in contemplating such an hypothesis; yet it is no more than the observed phenomena of light and heat force us to accept."

Again, the hypothesis of Gravitation forces us to believe that a particle of matter here, on this earth, is at this moment acting upon each other particle of matter in the universe, and that apparently with an action to which time counts as nothing, and the mass of all the planets as a thin screen offering really *no* opposition.

When we come to examine the hypotheses of Science, we find that they have been developed to very varying degrees of perfectness. "Where, as in the case of the planetary motions and disturbances, the forces concerned are thoroughly known, the mathematical theory is absolutely true, and requires only analysis to work out its remotest details. It is thus in general far ahead of observation, and is competent to predict effects not yet even observed, as, for instance, lunar inequalities due to the action of Venus upon the Earth, &c., to which no amount of observation, unaided by theory, would ever have enabled us to assign the true cause. . . . Another class of mathematical theories, based to a certain extent upon experiment, is at present useful, and has even in certain cases pointed

to new and important results which experiment has subsequently verified. Such are the dynamical theory of heat, the undulatory theory of light, &c. . . . A third class is well represented by the mathematical theories of Heat (conduction), Electricity (statical) and Magnetism (permanent). Although we do not know *how* heat is propagated in bodies, nor *what* statical electricity or permanent magnetism are, the laws of their forces are as certainly known as that of gravitation, and can therefore, like it, be developed to their consequences, by the application of mathematical analysis.

If it be impossible to group together the facts of Nature in every possible combination, and then to infer general laws; if it be necessary to make use of hypotheses, it may be asked—Is there no method applicable for forming these hypotheses? nothing to guide us in our guesses at Nature's laws? Of course it would be impossible to lay down *rules* for making hypotheses, just as it would be absurd to *teach* a man to be a genius; nevertheless, if we study the trains of thought by which the most eminent naturalists have been led to their great discoveries, we can arrive at some general idea of the methods which they have followed. These discoveries have evidently been guided by analogy. From one similarity, or from a few similarities noticed between different substances or between different sets of facts, they have inferred the existence of more points of similarity; they have then framed hypotheses which have guided them in their subsequent experimental investigations. To take an illustration:—When an electric machine was worked a peculiar smell was noticed; when a stick of moist phosphorus was allowed to remain exposed to air, a similar smell was perceived; when a hot glass rod was dipped into a mixture of either vapor and air, a similar phenomenon was perceptible. From these observed similarities Schönbien inferred that the cause of the peculiar smell was probably the same in each case, and following up this analogy by experimental investigation he discovered ozone—a substance which has played, and is doubtless destined to play, a most important part in general chemical theory.

Many instructive instances of the ap-

plication of analogy are to be found in the science of chemistry; in fact that science is almost entirely founded on more or less general laws which have been deduced by analogical reasoning. The fact that certain elements form groups having many common properties, and more or less sharply differentiated from other groups, has long been known. The further fact that there is, in many instances, a regular gradation in the atomic weights of the members of such groups, seemed to point to a connection between atomic weight and general chemical behaviour of the elements. Many facts were in keeping with this assumption. The connection between chemical properties and change in atomic weight has of late years been much attended to; and it has been shown by Mendelejeff and others that, if the elements be arranged in order of their atomic weights, beginning with that which has the least atomic weight, the general properties—not only of the elements, but also of their compounds—may be regarded as functions of the atomic weights; that, moreover, these functions are periodic,—that is, that groups of elements may be formed in order of increasing atomic weights, and that the general relations existing between, say, the third member of group two and the other members of the same group correspond with those relations which exist between the third member of group four and the remaining members of this group. Following up the analogy, Mendelejeff has propounded a hypothesis which goes under the somewhat ambitious title of the *periodic law*, and from this hypothesis he has made certain predictions. Among other predictions he has foretold the existence of elementary bodies other than those we are acquainted with: he has even ventured to assign certain properties to some of these hypothetical elements. Nor have his predictions been altogether unfulfilled. The most recent addition to the chemical elements is the metal gallium: in very many of its properties—in fact in its general chemical behavior, so far as this has been experimentally examined—gallium corresponds very closely with one of Mendelejeff's hypothetical elements. We have here an example of an hypothesis founded on analogical reasoning.

But analogy may mislead; it has often misled men in framing hypotheses. As telescopes were made of greater and greater power, astronomers found that the nebulae were resolved into clusters of stars. One by one these apparently gaseous masses were proved to be really aggregations of solid matter. Analogy suggested that all nebulae would be resolved when sufficiently powerful instruments could be brought to bear upon them. But meanwhile a new method of research was discovered; and by the use of spectrum analysis Huggins has proved that certain nebulae really consist of gaseous matter, and has therefore shown that the analogy in the structure of these bodies was not so complete as was supposed.

Analogy must evidently be used with caution. And here again we perceive the need of genius in Science. The ordinary man may amass facts, may even trace out a few analogies between groups of facts, but it is only the man of genius who will discover *the* analogy which will guide to great generalizations. Very probably even the genius will follow many false scents; but if he be a true student of Nature, besides being possessed of the divine gift of imagination, he will test his hypotheses framed on analogical reasonings by appeal to facts, and he will discover the true analogy and frame the correct hypothesis at last.

Of the vast masses of facts which are presented to the enquirer in each branch of Science there will be some of more value—considered as guides in deducing general laws—than others. Not unfrequently it happens that it is the fact which somehow refuses to fit in with the generally accepted hypothesis which becomes the means of guiding the investigator to a new and wider hypothesis. "When, in an experiment, all known causes being allowed for, there remain certain unexplained effects (excessively slight it may be), these must be carefully investigated, and every conceivable variation of arrangement of apparatus, &c., tried, until, if possible, we manage so to exaggerate the residual phenomenon as to be able to detect its cause. It is here, perhaps, that in the present state of Science we may most reasonably look for extensions of our knowledge; at all events we are warranted by the recent

history of natural philosophy in so doing."

As an illustration of the use made by genius of "residual phenomena" I might cite the discovery of the planet Neptune by Adams and Le Verrier. Slight anomalies were observed in the motions of Uranus: these were studied; the hypothesis was framed that the peculiar movements were due to the presence of an unknown body; observations were carried out, and the new planet was discovered.

Almost every science presents us with residual phenomena awaiting explanation. To mention one in chemical science. Why are the densities of the vapors of phosphorus and arsenic twice as great, and the densities of the vapors of mercury and cadmium one-half as great, as all analogical reasoning would lead us to imagine they should be? Here is an unexplained fact which will doubtless one day be prolific of consequences.

I have thus attempted to sketch the main points in that method which has been, and is, pursued by scientific men in their attempts to discover the truths of Nature: in conclusion I must say a few words regarding the limits of scientific method.

In science we start with facts, we then form hypotheses which we test by appeal to facts. But so great is the number of facts presented to us that we cannot observe or experimentally determine more than a small, almost an infinitely small, portion of them. Much less can we hope to form satisfactory hypotheses which shall explain them all. This is true in physical science. The mass of facts gathered together by the naturalist is already extremely large; but there can be no doubt that the number of the unknown vastly exceeds that of the known facts of Nature. And of the known facts how few have as yet been explained. The problem of the "mutual effects of three bodies, each acting on the other under the simple hypothesis of the law of gravity," can scarcely be said to be yet completely solved. And if this comparatively simple case has puzzled the ingenuity of the mathematicians what are we to say to the application of mathematical processes to the explanation of those motions and mutual actions which we have reason to believe are be-

ing performed and undergone by the constituent portions of every chemical atom? Each of these particles, Sir J. Herschel has remarked, is continually solving differential equations, which, if written out in full, might perhaps belt the earth.

In physical science our ignorance is practically infinite as compared with our knowledge; and when we come to mental and moral phenomena we are almost without any data on which to base strictly scientific reasoning. Each human being presents the phenomenon of a mass of conflicting hopes, fears, desires, passions, and inclinations which science can never hope to classify. How shall we measure these mental phenomena? How shall we weigh accurately the emotions even of the least emotional of human beings? What units shall we employ? How shall we calculate the effects of each human life upon the general life of the community? We cannot hope ever to reduce these things within the grasp of rigid quantitative analysis. As Prof. Jevons has truly remarked:—"As astronomers have not yet fully solved the problem of three gravitating bodies when shall we have a solution of the problem of three moral bodies?" And shall "victorious analysis" ever dream of attempting to bring under her formulæ the facts concerning man's relation to the physical world around him? If each set of phenomena, physical and mental, considered apart from the other, far surpasses our powers of investigation, how can science ever hope to approach the problem of the mutual relations of the two? "The air itself is one vast library, on whose pages are for ever written all that man has ever said or even whispered. These, in their mutual but unerring characters, mixed with the earliest as well as the latest sighs of mortality, stand for ever recorded—vows unredeemed, promises unfulfilled, perpetuating in the united movements of each particle the testimony of man's changeable will." We cannot solve the mystery of the physical world, nor the mystery of the mental world, nor the mystery of the connection between the two.

But we do attempt nevertheless to lessen the sphere of our ignorance and to change the unknown into the known. We endeavor to explain facts by group-

ing them together under a generalization. The wider generalizations of science are generally called laws. Having made a bold generalization, having appealed to facts and found that our generalization stands the test in any instance, we are very liable to conclude that this generalization *must* hold good in all cases, and to give to the expression a *coercive* value. Indeed, the name *law* almost implies coercive power. But are we justified in doing this? To say that the law must hold good in all cases implies infinite knowledge: we may have proved the law to apply in every instance which we have examined, but there is the chance that in the next instance it will fail. Prof. Jevons shows that "no finite number of instances can warrant us in expecting with certainty that the next instance will be of like nature." Every fresh instance of like nature to the preceding increases the probability that the law will hold good in all instances, but after all it is only a probability that we have gained. "The laws of Nature, as I venture to regard them, are simply general propositions concerning the correlation of properties, which have been observed to hold true of bodies hitherto observed. On the assumption that our experience is of adequate extent, and that no arbitrary interference takes place, we are then able to assign the probability, always less than certainty, that the next object of the same apparent nature will conform to the same law."

We speak of matter obeying the law of gravity. In this proposition we imply the existence of two things—matter and force; matter, a *something*, acted on by *another something*, force. Of these two things we cannot give very good definitions. Matter is "that which can be acted upon by, or can exert force;" and force is "any cause which tends to alter a body's natural state of rest, or of uniform motion in a straight line." But the force of gravity acting on particles of matter does not necessarily cause the actual approach of one body towards another; the action of this force upon a given particle of matter is conditioned by the number, mass, distance, and relative position of all the other particles of matter within the bounds of space at the instant in question. We must not for-

get that the action of the laws of Nature upon the matter of the universe is dependent upon the *collocations* (as Dr. Chalmers expressed it) of that matter at any moment of time. Given the same laws and the same mass of matter, but let the initial collocations of that matter vary, then the results would be altogether different for each collocation. No single law of Nature can be supposed to act independently of other laws. Every law is conditioned in its action by other laws. Or, perhaps, we should say that, in our ignorance, we are obliged to speak of special laws acting and reacting upon one another, when to infinite knowledge all would appear as under the control of but one law. But by us, at any rate, various laws must be recognized; and these are mutually related. Now if we cannot hope to know all the facts of the universe still less can we hope to comprehend all the laws thereof, and much less can we dream of arriving at a knowledge of the mutual actions of those laws upon one another, and the modifications in the action of one law upon material objects introduced by the interference of another law, or of other laws. And even our knowledge of individual laws is but approximative: the more carefully Nature is examined the more reason have we for disbelieving in the simplicity of her actions. At first everything appears chaotic; then fact group themselves together, generalizations are made, laws are framed. But after a time, as investigation proceeds, and as more exact methods are introduced, the law is found to be not quite in keeping with facts; the formula was only approximately true. There are slight exceptions, so slight that the older and ruder methods of research failed to detect them: the law is not rigorously exact. In the hands of the trained and able naturalist these small exceptions often prove stepping-stones to higher generalizations, which embrace in their enunciation the less widely applicable generalization. But if every improvement in our methods of research serves to point out exceptions to what were formerly accepted as general laws, are we entitled to assume that we have *now* reached the true generalization? Would it not be more becoming the spirit of true science to acknowledge our

ignorance, to remember that while we have made one step nearer the goal, that goal is itself still at an infinite distance from us?

I might illustrate this subject by reference to the researches of Cagniard de la Tour and Andrews upon the physical properties of gases, wherein it is shown that the laws in which Boyle, Marriott, and former experimenters enunciated the results of apparently complete investigations into the same subject were really only approximations to a solution of the problem. More recently Mendelejeff has shown, by very refined and laborious experiments, that Boyle's law is not strictly true, and he has paved the way for a higher generalization. But space forbids me to enter into these details.

We generally regard a well established physical law as acting continuously throughout all past time. Of course this is merely an assumption, yet it is an assumption which is apparently necessary in most cases if we are to attempt a scientific solution of the problems of the Universe. But there are good reasons for believing that certain very well established generalizations of science may not have held good during all past time. Sir Wm. Thomson has shown how to deduce (from Fourier's "Theorem of Heat") in certain cases the thermal state of a body in past time from its known condition at present, and one of the results of his investigation is the indication of "A certain date in past time such that the present state of things cannot be deduced from any distribution of temperature occurring previously to that date, and becoming diffused by ordinary conduction. Some other event beyond ordinary conduction must have occurred since that date in order to produce the present state of things. This is only one of the cases in which a consideration of the dissipation of energy leads to the determination of a superior limit to the antiquity of the observed order of things."

It is possible to imagine a law which should exhibit a break, or breaks, of continuity. Babbage has shown that it is theoretically possible to devise a machine which shall work according to a fixed law for any finite period of time, and yet at a fixed moment exhibit a single breach of the law. The machine might,

for instance, be constituted so as to continue counting the natural numbers for an immense period of time. "If every letter in the volume now before the reader's eyes," says Babbage, "were changed into a figure, and if all the figures contained in a thousand such volumes were arranged in order, the whole together would yet fall far short of the vast induction the observer would have had in favor of the truth of the law of natural numbers. . . . Yet shall the engine, true to the prediction of its inventor, after the lapse of myriads of ages, fulfil its task, and give that one, the first and only exception, to the time-sanctioned law. What would have been the chances against the appearance of the excepted case immediately prior to its occurrence?"

In the application of scientific generalizations we assume that the future will be as the present; we overlook, necessarily, the chance of sudden interferences with the present order of things. Yet we have no ground for denying the possibility of such interferences. There are facts which make the existence of numerous dark bodies in space very probable. How do we know that by the collision of one of these unseen bodies with this planet the present order of things may not be suddenly terminated? Have we investigated all the hidden springs of energy within the earth itself? Is there no chance of a sudden outbreak of some kind which will destroy this world and all its inhabitants in the twinkling of an eye? These suppositions are not unscientific; it is unscientific to assume complete knowledge when we really know almost nothing.

I think I have said enough to show that the scientific method is necessarily limited; that it leads us to recognize our own ignorance and the vastness of the problems presented for solution.

In an early part of this paper I said that by the aid of science we rise from the changing to the changeless; but if what I have said concerning the limitations of scientific laws, and concerning the unknown possibilities of Nature be true, it would appear as if the firm standing-ground we had seemed to gain were vanishing from under our feet. In a sense it is so; in another, and higher sense, the ground remains sure and firm.

Science, when we know our littleness and the greatness of Nature, exhibits to us the reign of law, but bids us beware of placing our partial interpretations upon her laws; she commands us to proceed in the investigation of facts, but to be very careful how we interpret these facts. We have learned enough already

to lead us to believe that although we can never fathom the mysteries of the Universe, the Universe is nevertheless obedient to order. If that little portion of the Universe which Science has conquered to herself be so wonderful in its organization and in its working what must the whole universe be?

## STEEL FOR SHIPBUILDING.

From "The Engineer."

THE enormous strides which have been made during the last few years in the manufacture of steel have, almost entirely, removed the objections which formerly were urged against its employment for shipbuilding purposes. Long ago it was felt that if steel could only be made so as to be thoroughly depended upon, and at a moderate cost, it would become a most valuable material for ship building, both on account of its great ductility, and from the additions which might be made to the carrying power of ships in consequence of the weight of steel scantlings being fully 20 per cent. less than that of iron of equivalent strength. Unfortunately, however, the difficulty of securing uniformity of quality and the great amount of nursing required during manipulation to prevent it from altering in its quality while being punched and sheared, as well as the necessity of annealing it afterwards in order to reduce it to its original temper, have hitherto debarred shipbuilders from freely employing it. The question of its use was discussed as long ago as 1868, by the Institution of Naval Architects, on which occasion Mr. Rochussen, of the Hoerder Iron and Steel Works, Westphalia, in his remarks on that subject, expressed an opinion which we knew him to hold, and probably with justice, that steel was not reliable, and not homogeneous, and that people who have spent a life in successfully treating iron, point with scorn at a steel plate which has split or snapped under circumstances where iron would not have sustained any injury. Thus steel yards have snapped in the truss, topmasts split in the fid holes, plates cracked on a sharp curve, and, saving

the possibility of bad material inherent to all human production, the quality of the steel may for all that originally have been unimpeachable. Steel had to be saved from its friends. The belief in its breaking strain was at first, unfortunately, based upon the knowledge of tool steel, and it was not uncommon to specify in construction steel equal to 42 tons to 45 tons per square inch. Happily, proper attention has been more recently paid to the peculiar nature of the material. Dr. Siemens has rightly pointed out that it is necessary that those who use it should know what it is, "for," he says "we hear of comparative results of steel and puddled iron as produced in one furnace and another furnace, and one would naturally come to the conclusion that steel was a definite compound, varying only as regards quality. But steel in the form of a needle, or an edge tool, or a punch is of a hardness approaching that of a diamond, and steel in the form of a spring is of an elasticity unequalled by any other metal, or any other substance in nature. Then, again, steel in the form of a rolled plate is, with few exceptions, the toughest material in existence, tougher than copper or wrought iron, and can be moulded into almost any shape in a cold condition. It is therefore of primary importance that you should understand first of all what quality of steel you have to produce, and that its manufacture and use in construction should be carried on with superior intelligence."

Special attention seems first to have been directed to steel for ship plates at Creusot and Terre Noire, and the confidence of the French Government in it

was gained to such an extent that they employed it throughout the hulls of their ironclads *Redoubtable*, *Tempete*, and *Tonnerre*, with the exception of the outer bottoms and rivets, which were made of iron. But Mr. Barnaby, in his paper on "Iron and Steel," read before the Institution of Naval Architects in 1875, pointed out the extreme amount of nursing which was required in its manipulation and quoted from the pamphlet written by M. Barba, *Ingenieur des Constructions Navales* at L'Orient and published the same year, in which it is stated that "if it is impossible to work the plates without hammering, or without local pressure of great severity, or if the curvature given is considerable, it is necessary to proceed with care and skill to avoid ruptures in the course of the operation. The hammering ought to be done with light blows, delivered over as large a surface as possible; and the curvature ought to be produced not at once, but by successive stages." Commenting on this, Mr. Barnaby very pertinently remarked that a material which needed such care in its treatment would stand but a very poor chance in an ordinary shipyard, and concluded by challenging the steel manufacturers in this country to produce a material which we could use without such delicate manipulation and so much fear and trembling. This challenge was taken up by many manufacturers, with the result that a contract was given to the Landore Siemens Steel-works to supply steel plates and angle bars for the *Iris* and *Mercury*, building at Pembroke. This material was subjected to the ordeal of a series of most severe tests, which proved the extraordinary ductility of steel manufactured by the Siemens-Martin process; for these experiments may be taken to apply equally fairly, not merely to Landore steel, but also to that manufactured at Bolton, Sheffield, Workington, and Glasgow. Although in the production of very mild plates and bars the Siemens-Martin process was at first the more successful, equally good results have been since obtained in Bessemer converters, and indeed at Bolton, where both processes are in operation, the Bessemer converter is preferred to the open hearth system. This mild steel is endowed with some peculiar characteristics, which render it more fitted for

shipbuilding purposes than even best iron.

In the first place, its tensile strength is about 30 per cent. greater than that of best iron, and it has much greater ductility and uniformity, together with a capability of application to any of the purposes to which Lowmoor or Bowling iron have been applied, such as flanged garboards, keel plates, bow plates, &c. Then, again, it is equally strong both along and across the plate, and it is said to be infinitely less distressed by punching closely-spaced lines of rivet holes, even when annealed, than any iron would be.

Of course it is an advantage to anneal the plates after working and bending them, but it is by no means absolutely necessary, as has been sufficiently proved by the quenching test, which consists of heating the plate to a cherry red, and then plunging it into water. Its beautiful surface and freedom from exterior defects also renders this mild steel peculiarly applicable for the outside plates of vessels, and a series of experiments made by M. Gautier at Terre Noire, extending over about three years, established the fact that when exposed to the action of sea water mild steel suffers from corrosion only in the proportion of 60 to 140, when compared with the effect of similar treatment upon iron plates.

The only matter which has to be specially attended to in the employment of steel in shipbuilding operations is welding which requires great care and experience if the welds are of any length—several heats being required—otherwise the same treatment as that given to ordinary iron plates is quite sufficient. For the construction of the top sides of men-of-war, and for torpedo boats, mild steel possesses the great advantage of standing the fire from Gatling guns and rifles much better than iron of equal thickness. So far, we see that the advantage of mild steel over iron for ships is undoubtedly very great, and the only question on which its further employment will depend is the matter of cost of production. Hitherto the price of steel has been so high that the saving in weight, and consequent increase of cargo-carrying power, by reductions of scantlings, has hardly been sufficient to compensate for original increase of cost of construction. The im-

provements, however, which have been made in its manufacture have also been in the direction of simplifying the process of production, and therefore reducing the cost. Already mild steel is much cheaper than Lowmoor and Bowling iron, and hopes are held out by the manufacturers that as the demand increases they will be able to reduce the price much more. That this material has at last been brought to such a state of perfection, combined with cheapness, as to make its application to mercantile ships desirable, has now been recognised by Lloyd's Registry. We last week published a report they had received from their chief surveyor and his assistants, together with notice of a set of regulations they have passed for classing ships built of steel. Hitherto all steel ships have been classed as "Experimental," but we are now glad to see that they are to have a regular class, for we cannot help thinking that the "Experimental" classification helped to kill the use of steel in 1868, and materially kept back its improvement.

\* A general reduction of 20 per cent. in the thickness of plating, frames, &c., is to be allowed in future in steel ships, and iron is only to be used for rivets, keel, stern, sternpost, rudder, pillars, girders, and top of inner bottoms of the usual size, but no other parts without the special sanction of the committee. The surveyors will have, however, to exercise great care and attention in this reduction of scantlings to make ample provision

by means of stiffeners against buckling. This we have no doubt they will do, and steel will now have, we trust, a fair field and no favor. But we would impress upon the manufacturers in this country, that perfect as the mild steel is which they are now producing, they must by no means be content to rest upon their work, for, as M. Gautier's able papers at the last two meetings of the Iron and Steel Institute show, the French makers are still rapidly advancing, and with the great advantage they possess in having the most suitable ores at hand, are likely in the long run to outdistance our makers unless the latter look well to their laurels. That there is a great future for steel in shipbuilding is now evident, and we must congratulate the Admiralty in taking the step they have done in initiating its use, and placing the results of their experience so unreservedly at the service of private shipbuilders, which undoubtedly had much to do with bringing on its improvement to its present state. It must not be forgotten, however, that there is steel and steel, and the greatest caution will be required on the part of makers and purchasers to secure a satisfactory result. Steel has failed disastrously more than once as a material for the construction of ships, and although nothing of the kind need occur again, it must always be borne in mind that steel is a peculiar material to deal with, and very unlike iron in its behavior.

## LIGHTING BY ELECTRICITY.

From "Journal of the Society of Arts."

THE discovery of electric induction by Professor Faraday in the year 1830 drew the attention of the scientific world to the possibility of utilizing motive power as a means of generating a current of electricity. Faraday demonstrated before the Royal Society that if a magnetised bar of steel be introduced into the center of a helix of insulated wire, there is, at the moment of introduction of the magnet, a current of electricity set up in a certain direction in the insulated wire forming the helix, while, on the withdrawal of the magnet from the helix, a

current in an opposite direction takes place. He also discovered that the same phenomenon was to be observed if for the magnet was substituted a coil of insulated wire, through which the current from a voltaic element was passing; and further, that when an insulated coil of wire was made to revolve before the poles of a permanent magnet, electric currents were induced in the wire of the coil. It is on these discoveries that are based the action of all magneto-electric machines.

Amongst the variety of patents that

have from time to time been taken out, both in England and other countries, for magneto-electric machines, there is no doubt that a large proportion are only slight modifications or re-discoveries of already existing machines. Some idea may be formed of what has been done in this branch of electric science, if we take as types of magneto-electric machines those of Pixii, Saxton, Clarke, Henley, Nollet, Siemens, Wheatstone, Ruhmkorff, Wilde, Pacinotti, Holmes, Breguet, Gramme, and Niaudet. Perhaps, before mentioning the practical application of these machines, more especially as a means of producing the electric light, a few remarks by way of explanation of some of them may not be without interest.

Pixii was probably the first who practically carried out Faraday's discovery and constructed a magneto-electric machine. His machine consisted of a wooden frame, working in which was a small vertical spindle, carrying on its upper extremity a permanent horse-shoe magnet; underneath this, on the lower part of the spindle, was fixed a pinion driven by a suitably arranged bevel wheel, so that, by turning a handle, the magnet was made to revolve rapidly. Directly above the horse-shoe magnet was fastened to the wooden frame an electro magnet; and the poles of the two magnets were brought as near as possible together without actually touching. On the magnet being made to revolve, its poles passed those of the electro-magnet, thus setting up a series of reversed currents in the wire of the electro-magnets. As for many purposes it was necessary that the currents should always be in the same direction, to obviate these reversals a small circular commutator was placed immediately below the permanent magnet and fixed to the vertical spindle revolving with it. On this commutator four springs were made to press; two were connected to the ends of the wire forming the coils of the electro-magnet, the other two springs to the two terminals of the instrument from whence the currents of electricity generated are given off. By a very simple arrangement of commutator, not needing explanation, it will be readily understood how the two springs connected to the coils of the electro-magnet may, through the

commutator, be put into alternate connection with the two springs connected to the terminals in such a manner that the + currents are always directed to one spring, whilst the - are communicated to the other; so that one terminal becomes the positive and the other negative.

The electricity generated by this class of machine is not a continuous current, but rather a series of currents in rapid succession; although, when the machine is made to revolve at a high speed, the currents are generated in such quick succession that they form a sufficiently continuous current for many purposes.

In Saxton's machine both the permanent and electro-magnets were placed horizontally, and made to rotate end to end. The proportional size of the electro-magnet, with reference to the permanent one, was reduced, as it has been found experimentally not to be desirable to have so large an electro-magnet, in proportion to the permanent magnet, as had been given in Pixii's machine, while there was a great advantage in increasing the power of the permanent horse-shoe magnet.

These machines were only adapted to laboratory and scientific experiments, for which purpose fair results were obtained.

Clarke's machine (a name frequently erroneously given to all classes of alternating current machines) is well-known in connection with small magneto-machines, more especially such as are constructed for medical purposes. The machine differs somewhat from either that of Pixii or Saxton. Clarke took advantage of the fact that the greatest strength of a magnet is situated at a small distance behind the poles, and not at the extremities themselves, and constructed his machines in such a manner that by placing the electro-magnets at right angles to the permanent magnet, its poles were made to pass over those of the permanent magnet at the point where the greatest strength was to be obtained. The machines were made in a very compact form; a commutator fixed on the spindle carrying the electro-magnets, by a simple arrangement, corrected the reversals of the current generated, so that the electricity obtained at the terminals of the machine was

always made to flow in the same direction."

It was not long after the establishment of the electric telegraph in England, that attention was directed to the feasibility of utilising the current generated by magneto-electric machines, for telegraphic purposes. Mr. Henley about this time, having made several experiments in this direction, succeeded in bringing out then a great novelty, his instruments for telegraphic purposes, whereby the use of a galvanic battery was entirely dispensed with. It was with these instruments that for some time the Magnetic Telegraph Company carried on their electric communication.

The system was after a time, however, superseded by the use of batteries, it not having been found to be so advantageous in practice as had at first been anticipated. Perhaps one of the simplest forms of magneto-electric machine then used for telegraphy was Henley's so-called thunder pump, an instrument employed for ringing bell signals for telegraphic purposes. It consisted simply of an ordinary horse-shoe permanent magnet, above which was arranged a small lever. On one end of the lever was an electro-magnet, the poles of which, when at rest, were touching those of the permanent magnet; by depressing the other end of the lever, on which a suitable handle was attached, the electro-magnet was raised from the poles of the magnet, and by this means a momentary current was induced in the coils of the electro-magnet. The wires from the coils were connected to the line, and so to the bell at the receiving station; thus every movement of the handle caused a ring on the bell, by this means calling attention. Modifications of this instrument were also used to work double needle instruments, and were in practical use for a considerable time.

While speaking of the application of magneto-machines for telegraphic purposes, it may be well to say a few words on those of Messrs. Siemens and Halske, and of Wheatstone. One of the most important improvements in these machines since that of Clarke was the Siemens and Halske machine, first brought out about the year 1854. In this, instead of using the ordinary form of electro-magnet, that had up to

that time been employed, it was replaced by a cylindrical bar of soft iron. The bar had four longitudinal grooves cut in it from end to end, its cross section resembling a double T. In the grooves, insulated wire was wound parallel to the axis of the cylinder in such a manner that the iron core and insulated wire formed a complete cylinder. The end of the wire was soldered to the axis of the cylinder, while the other was fixed to a small insulated metal ring at the extremity of the axis; on this ring a spring connected to one of the terminals of the machine was made to press, the other terminal being connected direct to the axis. The poles of a permanent magnet were so formed and arranged that they were made to embrace the cylinder, to which they were placed as close as possible without actually touching. This form of machine, while generating a powerful current, had the advantage, from the close proximity of the iron cylinder to the poles of the permanent magnets, that these did not so readily lose their magnetism, as the iron cylinder, when at rest, acted as a keeper to the permanent magnets. Siemens and Halske's well-known form of A B C instrument is worked by the currents generated by a magneto-electric machine of this construction. Some great improvements have lately been made in the machines, more especially those designed by them for electric-light purposes; in these the permanent magnets are replaced by electro-magnets, actuated by currents generated by the machines themselves. Improvements have also been made in the arrangement of the commutator, whereby the evils caused by the inductive spark are in a great measure reduced.

The Wheatstone machine, familiar to most persons in connection with the A B C instruments in general use on private wires in England, as it is from currents generated from these machines that the instruments are worked, differs in many points from any of those already described; as employed for A B C instruments, they consist in attaching to the poles of a permanent compound magnet a set of four bobbins, the soft iron cores (pole pieces) of which are fixed permanently to the magnet, two to each pole. Immediately in front of these

cores a soft iron armature is placed, and arranged so as to revolve in front of the cores on the handle of the machine being turned. The cores of the bobbins, being fixed to the poles of the magnet, receive polarity from them, thus forming four poles, two of which are south and two north. On the armature in turning, passing in front of these poles currents, are induced in the wire forming the bobbins, and these, by suitable connections, are made to actuate the needle on the dial of the A B C receiving instrument.

One of the chief advantages of this arrangement is that the wire of the bobbins is connected direct to the instrument without the interposition of any commutator, rendering the liability to failure through faulty contact in the commutator impossible.

The employment of induced currents from magneto-electric machines has not, however, in practice, been found to give such good results for telegraph purposes as at first sight might have been imagined. Currents generated by these machines are at comparatively a high state of electric tension, necessitating, accordingly, high insulation; and this on lines of any extent is found difficult to sustain, so that the employment of this class of instrument has been confined in a great measure to private wires and similar short lines; even with these it is found that the insulation requires a good deal of attention to maintain.

The magneto-electric machine, patented by M. Nollet in 1850, but now more generally known under the name of the Alliance machine, was originally intended by the inventor as a means of decomposing water by the currents so generated; the hydrogen gas, produced after having been passed through camphine, or some hydro-carbon oil, to be used for lighting purposes. The inventor also proposed to form an explosive mixture with the hydrogen, making use of the explosion as a means of obtaining motive power, in a suitably arranged engine. It is more than probable that the Alliance machine would never have been brought to anything like a practical success had it not been for M. Van Malderen, a former pupil of Nollet's.

The Alliance machine, as at present constructed, consists of a number of cir-

cular gun metal discs, arranged and mounted upon an iron shaft, running in a horizontal position between the bearings of two frames that contain the machine. Near the circumference of each of these disc are fixed a series of 16 bobbins with soft iron cores, arranged equidistant and parallel to the shaft, free to turn with the discs between the poles of eight horse-shoe permanent magnets fixed in the frame. The poles of these magnets are placed radially towards the center of the shaft. The faces of the magnets are placed parallel to the discs, so that in each circumference there are 16 poles, equivalent and corresponding to the 16 bobbins. The machines are ordinarily made with either four or six discs, so that in the one case there would be 64 bobbins and 40 permanent magnets, and in the other 96 bobbins and 56 magnets. On the shaft is a pulley by which the machine is driven by means of a band. The bobbins are connected up in series, and one end of the wire is fixed direct to the shaft, the other to an insulated ring on it, or, as frequently arranged, one part of the shaft is insulated from the other; to these are connected the terminals of the machine.

On setting the machine in motion, it is clear that every time a bobbin passes in front of the pole of one of the magnets, a momentary current will be induced in it, varying in direction according as the pole is either north or south. Thus, in each revolution of the discs as the bobbins will have passed the sixteen alternate poles of the magnets, there will have been induced sixteen alternate currents. The machine is run usually at a speed of 400 revolutions per minute, so that in each minute there will be 6,400 alternate currents generated (about 100 per second).

One of the chief advantages of this machine is its compactness and non-liability to get out of repair; no commutator is used, the currents generated being a series of reversals. For electric light purposes they have in France until very recently been the principal machines used. At the Hève and Grisnez lighthouses they are still employed, as also at many other places for lighthouse lamps, apparently as alternating current machines giving satisfaction. Probably it is owing to their rather high price that

their adoption has not been so universal as might have been expected.

The Holmes machine, first patented in England in 1856, differs somewhat from the one just mentioned in the manner in which the bobbins are arranged; these are held between two brass discs in two or more concentric circles, the bobbins rotating in front of the poles of a number of permanent magnets fixed to the frame and radial to the axis of the machine. By this means the bobbins are passed in quicker succession in front of the poles of the magnets, and so per revolution a greater number of currents generated. This arrangement allowed of the machine being run at a slower speed. A commutator was placed to direct the alternating currents and cause them to be given off from the machine in the same direction.

Since his original patent, Mr. Holmes has made a large number of experiments and improvements in his machines. This machine was the first one used practically in England for the electric light for lighthouse purposes. On the evening of the 8th December, 1858, it was for the first time exhibited from the high light at the South Foreland, and remained at work until the 30th of the same month, after which it was worked at intervals until the 6th of June 1862, when it was permanently fixed at the Dungeness Lighthouse, and there it has since continued to be used.

In designing his first magneto-electric machine for the Trinity Board, Mr. Holmes had considerable difficulties to contend with. It was made a *sine qua non* by the Board at that time, that the speed of the machine should be limited to about 100 revolutions per minute, and driven by a direct acting steam-engine, without the intervention of either strap or band. These stipulations made it necessary to make the machines of a much larger size than anticipated. In this peculiar machine it was calculated that in every revolution eighty-five pounds of soft iron were magnetized, N-S and S-N forty-four times. As the speed of the machine was 110 revolutions per minute, there were, consequently, 4,840 reversals of current per minute.

Great care had to be observed, both in the selection of the steel and manu-

facture of the permanent magnets for this class of machine, in order, that they might take up and retain a maximum quantity of magnetism. In Mr. Holmes' latest patent, to obviate this, he replaces the permanent by electro-magnets, a part of the current of the machine being utilized for magnetising them. The magnets are made to turn while the bobbins are fixed; these are coupled up in such a manner that he is enabled to take off a number of independent currents and thus supply currents for a number of lights, or other purposes, from the one machine.

Wilde's machine resembles somewhat two Siemens' machines of unequal size, the smaller one being placed on the top of the larger. The current from the small one is used for magnetizing two powerful electro-magnets of the larger machine, these replacing the permanent ones ordinarily used in the Siemens'. Very fair results have been obtained from this apparatus, although the same drawback exists in this as in all alternate current machines, from the difficulty that arises in presenting the injurious effects of the inductive spark at the commutator, which, besides burning away the contacts, causes the machines to heat. Many ingenious arrangements have been brought forward to obviate this difficulty; but although they have greatly reduced the ill effects arising from the inductive spark, they have never been entirely prevented.

The Gramme machine differs essentially from those above described in a point of the greatest importance, viz., that instead of its generating a succession of alternating currents, the current is continuous, and in the same direction; hence the difficulties arising from the inductive spark are entirely overcome. The machine is an important advance in the construction of magneto-electric machines. Looking at its simplicity, it seems curious that the idea of utilizing the principle involved should not have occurred to some of those who have given so much of their attention to the construction of magneto-electric machines.

To understand the principle on which the Gramme machine is based, we must refer to Faraday's original experiment of a helix of insulated wire and a permanent magnet. From this it is evident that, in

passing a magnetized bar of steel through this helix, a current in a certain direction will be induced in the wire of the helix until such time that it has reached the neutral point of the magnet (the center of the bar). Further, the direction of the current will be reversed during the passing of the remaining portion of the magnet.

Now, by way of illustration, against this magnet, which we will call A, let another similar one, B, be placed with their like poles touching, supposing, so to speak, that there is thus formed one long magnet with a similar pole at each extremity, and the contrary pole at the point of juncture of the two magnets. In passing the compound magnet thus formed through the helix it will be observed, from what has been above stated, that whilst A is being passed through the helix a current will be induced in one direction, until it has reached the center of A, when the direction of the current will be reversed, and remain so until it reaches the center of B, when it will again be reversed to its former direction.

Now, in the place of the bar-magnet, let us take two magnets bent into half-circles, and place them with their like poles touching, forming thus a ring in which the two poles N and S will be on opposite sides of the ring. The neutral points of the magnetized ring will, therefore, also be on opposite sides, and a line drawn through these would be at right angles to one drawn through the poles, cutting it at the center of the ring. In passing a helix of wire once round the ring, it will be observed that during each half of the revolution an opposite current will be induced in the wire of the helix, the current altering in direction each time the helix passes the neutral points.

In the Gramme machine, for this ring magnet is substituted a ring of soft iron (usually composed of a number of wires) made to revolve between the poles of a permanent magnet. By this means the iron of the ring becomes magnetized by induction, the poles remaining always in the same relative position to the magnets, at no matter what speed the ring may be made to revolve. The neutral point of magnetism in the ring would, therefore, be situated in a line drawn at right

angles to one drawn through the poles. Round this ring of soft iron are wound a number of bobbins of insulated wire, connected to each other in series, so that it forms, as it were, one continuous coil of wire, completely covering the soft iron ring. At the points of juncture of these bobbins, connections are made to each strip of a commutator fixed on the axis of the machine. The commutator is composed of a number of metal plates, insulated one from another, and fixed radially to the axis of the machine. The outside of the commutator is turned true, forming a cylinder, presenting on its surface alternate strips of metal and the insulating material used. Two brushes of copper wire are made to press upon this commutator—one on each side. The connections are so arranged that these brushes will always be in contact with the two opposite bobbins that are at the time in the neutral positions with regard to the induced magnetism of the ring, that is to say, at points equidistant from the two poles.

If the ring, with its bobbins, be made to revolve, it is evident that two currents of electricity in opposite directions will be induced in the bobbins, one in one half of the bobbins on the ring, and the other in the other half. These halves being divided by the neutral points of magnetism the currents would be equal, and, consequently, annul one another, were there no connection made with the commutator; but, as the brushes pressing on the plates of the commutator will be thus connected to the bobbins, it follows that, if the brushes were connected by a wire, a current would flow along this wire equal in quantity to the sum of the two currents generated in the bobbins. In fact, the same phenomenon takes place as occurs in two galvanic elements of equal strength when the like poles are joined together (connected up for quantity); the two currents, being equal with, but opposite in direction, annul one another, no action taking place. When, however, the two poles thus formed are connected to each other, a current is generated in quantity equal to the sum of the two elements, which, in reality, it is.

The brushes are connected to the two terminals of the machine, one to each, and regulated so as always to be in con-

tact with the coils, not breaking contact with one until the contact is established with the next one. By this means, when properly regulated, the current is perfectly continuous, and therefore no induction spark takes place.

The Gramme machines are very compact and complete; every attention has been paid in designing them to render them serviceable for continuous work.

In the small machines for experimental use, permanent magnets are used, the poles being brought down and fixed to soft iron pole pieces cut away so as to embrace a large extent of the circumference of the ring. The larger machines used for electro-plating, electric light, and such like purposes, have the permanent magnets replaced by electro-magnets, which are excited from the current generated by the machines themselves. In practice it is found that these electro-magnets always retain a sufficient quantity of residual magnetism to generate a weak current on starting the machine. This current, passing through the electro-magnets, increases their magnetism and re-acting on the bobbins, increases the current from the machine, which in its turn again acts on the electro-magnets and so on, until the current has reached a maximum strength corresponding in proportion to the speed of the machine. The speed of the Gramme machines varies from about 500 to 1,000 revolutions per minute, according to the object for which they have been designed.

Niaudet's machine is in principle similar to that of a Gramme machine; the current is continuous. In this machine a number of bobbins with soft iron cores are fixed parallel to an axis with which they revolve. The poles of these bobbins turn between the poles of two horseshoe permanent magnets, one magnet being placed at each end of the bobbins, in appearance somewhat resembling two Clarke's machines placed back to back. The bobbins are joined up in series, with connection made at the point of juncture, to a commutator, similar in principle to that of the Gramme. Two contact springs make the connections to the terminals of the machine.

It is unnecessary to give any further description of the various forms of magneto-electric machines that have been brought out. <sup>2</sup>/<sub>3</sub> From those already de-

scribed a fair idea may be formed of the advance that has been made in this branch of electrical knowledge, with regard to the construction of this class of apparatus. It remains, therefore, to be seen in what manner the electricity generated by this means has been practically utilized.

The earlier machines were little else than philosophical toys, and, excepting for demonstration, were very little used. Probably their first practical application was that for working telegraph instruments. For this purpose up to the present time they have been for certain classes of work in extensive use on short lines. One of the chief objections to a more widely extended use has been, that the currents so generated are at a high state of tension, rendering the insulation of the lines difficult to maintain.

The Gramme machine, with the coils of the ring wound with large wire, giving a continuous quantity current, has been proposed for use in lieu of ordinary batteries for working telegraph circuits. The objections to its use are purely of a practical nature, but until solved they will preclude its adoption for this purpose, although, were it feasible, a great saving both in labor and maintenance would result in large telegraph offices.

Some of the earliest applications of magneto-electric machines were for electro-plating, but their employment was very limited, and confined only to a few isolated cases. Since, however, the introduction of the Gramme, their use has become somewhat more extended for electro-metallurgic purposes. Their use in connection with the electric light is perhaps the one for which they have proved themselves most valuable. They replace batteries expensive both to work and maintain, indeed, so much that, although the phenomena of the electric light was well understood prior to the introduction of these machines, yet no practical use had been made of it. For lighthouse lamps the electric light has proved invaluable. Mr. Holmes, as already stated, was the first who successfully applied it in England for this purpose. The machine was exhibited at the 1862 Exhibition prior to its erection at the Dungeness Lighthouse. In France, the Hève Lighthouse, near Havre, was the first that was fitted up with the elec-

tric light, in 1863; in this case the Alliance machine was employed. In both these instances such good results were obtained that the system rapidly spread. It is now acknowledged to be the best system in every respect in all places where it can be applied.

In utilizing the electric light for light-houses, or other purposes, there are many points that require attention; and it is, perhaps, not the simple matter that might at first appear. Like everything else, it has its drawbacks and inconveniences as well as its good points. Still, whilst for lighthouses, and for many other purposes, it may be economically applied, yet, with our present knowledge of the subject, it requires a vast amount of further development before we can hope to see our streets lighted up by its means.

To generate the electric current, a motor of some description must be used to drive the magneto-electric machine; the function of the latter, as already explained, being simply that of converting the motive power into electricity. The power required will vary in strength in direct proportion to the current to be generated. For the smallest machines of any practical value for light purposes from two to three horse power is found most convenient, representing about 1,000 candle power.

The usual method of obtaining the electric light, and the principle on which the lamps are ordinarily constructed, is that of employing two carbon electrodes, between the extremities of which a current of electricity is made to flow. In doing this a most brilliant light is produced, depending in intensity upon the quantity of electricity employed. That a uniform and steady light may be maintained, the lamp, which consists of some kind of regulator, has to be so constructed that the carbon points are automatically kept at the same distance from one another; so that the resistance of the circuit remains constant. The three principal functions that a properly constructed electric lamp should automatically fulfill are these:—1st. That on a stoppage of the current from any cause the points of the carbon are brought together, completing the circuit—ready for action on the current being re-established. 2nd. The carbons, when burn-

ing, must be held a short distance apart; and 3rd. The carbons must be brought together whilst burning at the same uniform rate as the combustion takes place, so keeping the distance between them constant.

In fulfilling the above-mentioned requirements, the Serrin lamp has probably given the best results, having passed through the stage of a philosophical toy, and been employed for some years past in real practical work. The principle of this lamp is used more or less in all the varieties of electric lamps, and, therefore, from a short description of it, the method in which the lamps are ordinarily constructed will be understood.

The Serrin lamp consists of two carbon holders made of brass, placed vertically one above the other; the upper one, to which the positive pole is attached, is held in position by means of a cross piece fixed to a vertical rod placed a few inches away from the carbon holders. This rod and the lower (negative) carbon holder are made free to move, either up or down, in two brass tubes that are fixed to the top of the case containing the regulating apparatus. On the lower extremity of the rod fixed to the upper carbon holder, is a rack that engages in the teeth of one of the wheels of a small clock-work movement. The end of the rod is so weighted that, by its own weight, it has a tendency to drop, and in doing so turns the clock-work; this, in turning, winds up a chain fastened to the lower extremity of the lower (negative) carbon holder; so that by this means, as the positive holder falls, the negative one rises, and thus brings the carbon points closer together. On the last pinion of the clockwork is a small fly, so arranged that a stop in connection with an electro-magnet prevents the fly from turning so long as the magnet is exerting a certain force. This magnet is circuit with the lamp, and thus, as long as the lamp is burning with a certain regulated current, the fly is held from turning; consequently the carbons are held in their position, remaining so until such time as they have burnt away slightly. This will cause an increased resistance, from the distance between the carbons being greater, when a corresponding diminution of the current takes place, weakening the force of the

magnet; this releases the fly, and allows the carbons to approach one another until the resistance is again regulated, and the magnet sufficiently powerful to stop the fly.

The lamp is very ingeniously arranged, and it would be impossible without diagrams to explain a variety of other details that do so much in establishing its success. Suffice it to say that the lamp is so constructed that, by a neat movement, while there is always a sufficient and surplus force exerted for bringing the carbon points together, at the same time, on the circuit being broken, these carbons are automatically brought together without the possibility of the points getting crushed. When employing a continuous current, the positive carbon is consumed at about the rate of the negative; this is also compensated for in the lamp, so that the light is always maintained in the same position.

One of the inconveniences in using the electric light, is that of the carbons having to be replaced about every four hours. To obviate this, it has been suggested to employ two round discs of carbon slowly revolving, their edges touching, the light being formed between these two edges. The first automatic electric light regulator was, on this principle, made by Thomas Wright, in 1845, afterwards improved by Molt and others, but never sufficiently perfected to render it a success. At the present time, a further modification of the principle by Mons. Regnier, is being experimented upon at Chemin de Fer du Nord, Paris, but with what amount of success it is premature to say. M. Regnier, however, expects to be able by this means to arrange lamps burning for twenty-four hours without alteration.

Notwithstanding the foregoing remarks may at first sight appear to put great difficulties in the employment of electric light for commercial purposes, the system has of late been introduced with very satisfactory results. It has made considerable progress in advantageous application; more, perhaps, so in France than in any other country, the Gramme machine and the Serrin lamp being the system almost universally adopted.

Among some of the principal places in France where the system is at work on a

commercial scale, and apparently with success, are, Messrs. Saulter, Lemonier, and Co., lighthouse manufacturers, Paris, in their fitting and turnery shops; the chocolate works of M. Menier at Noisiel, also at his india rubber works at Grenelle (Paris), as well as at his sugar refinery at Roye; Messrs. Cail and Co., engineers, Paris, in their locomotive erecting shops; and the Chemin de Fer du Nord for part of their goods station of La Chapelle.

For out-door work there is no question, in many cases, of the advantage of the electric light. By this means an extended area can be readily lighted up, and this in places where gas, probably, cannot be employed.

It is claimed that the cost of working this system is cheaper than that of gas—and, perhaps, in certain cases, this may be the case—but it is very difficult, for obvious reasons, to draw any comparison between the electric light and gas. There is nothing more misleading than a statement of an electric light being of a certain candle power, when comparing its cost with a number of gas burners. In the one case you have a certain candle power of light concentrated, so to speak, in one small spot, probably not giving the advantage of one-half the light; whereas in the other, with gas, the light being divided, is more diffused.

The deep shadows, where so powerful a light as the electric is used, have to a great extent been successfully obviated by keeping the light raised a good height from the ground. When under cover the walls and roof of the building should be kept whitewashed, and one lamp placed in opposition to another; not using reflectors has been found advantageous.

At the La Chapelle Station the lamp (one being at present used) is enclosed in a large lantern, the sides of which are opaque to about half their height, so that the naked light is not visible from any part of the building. Any use, however, of opaque glass, although diffusing the light, must at the same time diminish its candle power very considerably. With low pitched roofs it is found very difficult to sufficiently diffuse the light.

A few weeks ago, as an experiment illustrative of the value and practicability

of the electric light, the Gramme Company in France undertook to light up the Palais de l'Industrie at Paris by this means.

The building, which has a superficial area of about 2.5 acres, was lighted up by two clusters of six lamps each, naked lights suspended from the roof, distant from each end of the building about one quarter the length. The lamps were worked by 12 small Gramme machines driven by two 25 horse-power engines that were placed outside the building. By this means the entire building was sufficiently well lighted up to enable a newspaper to be read at any part of the building. No inconvenience was experienced to the eye when looking at the lights; their height prevented this. The light had a peculiar white appearance, and colors were as readily distinguishable in it as in daylight. The shadows were very slightly stronger than those of ordinary daylight, and by no means marked. As to the lighting up of the building and its practicability, it was a decided success, although with regard to the cost, in comparison with the gas, there were no means of ascertaining.

In the above special mention has been made of the Gramme machine, as it has been the one most extensively used for lighting purposes; however, with any of the other machines previously mentioned, probably similar results might be obtained, each one having its own particular points of excellence.

At the commencement of last June, some trials of the capabilities of a recent invention, "the electric candle," as demonstrating its suitability for dock purposes, were carried out at the West India Docks, permission having been granted to the patentees by the Dock Company.

The electric candle is the invention of M. Jablochhoff, a Russian engineer officer. It consists of two carbons placed side by side, with a strip of kaolin (china clay) insulating them from one another.

M. Jablochhoff had found that kaolin as soon as it became heated, diminished the resistance of the circuit sufficiently to permit of the electric light being formed between the carbons; also that, by the intense heat concentrated at

this spot, the kaolin was volatilized; so that, in fact, when the "candle" was once lighted, it gradually burnt down, much in the same way as an ordinary candle.

The experiment at the docks were, unfortunately, not quite so successful as some that have been more recently carried out in Paris, although, in a great measure, they demonstrated the practicability of the invention.

One of the chief advantages claimed by the inventor is that he is thus enabled to divide the circuit into a number of different lights, as the resistance of the circuit is constant, whereas, by the ordinary system, this cannot be done, it being necessary to have a separate machine for each lamp.

The invention is certainly very pretty and a good deal may be said in its favor; although, as to the practical advantage to be derived from it, with our present knowledge of the subject, and its great superiority over the ordinary system, is an open question.

One thing must not be lost sight of, namely, that the distance to which the current of electricity can practically be conveyed for light purposes is very limited; in fact, about 200 yards is the limit; so that the advantage of dividing the light by means of the electric candle is not so great as at first sight might appear, while the amount of light obtained when the circuit is divided is not so great as when one lamp only is used. True, the light is more diffused, but then a number of lights have to be attended to in the place of one, and the advantage claimed is not evident.

With the electric candle a neat form of lamp is used, which, by means of a simple mechanism, throws a fresh candle into circuit as soon as one has burnt out. The lamp is usually arranged with four candles, each burning about three hours, but the number of candles in the lamp could of course be increased if necessary.

Another plan of electric lights, also the invention of M. Jablochhoff, is that of passing a current of electricity through a piece of kaolin, which is thus rendered incandescent; by this means it is claimed that he can divide the current into a number of lights equal each to that of an ordinary gas burner.

From what has been already said, it is

evident that there are a number of useful purposes to which the electric light may be both advantageously and economically applied, but that the time when

it will fill the place of our present system of gas lighting, notwithstanding the rapid advance of electrical knowledge, seems as far off as ever.

## ELEMENTARY CONSIDERATIONS BEARING ON THE NATURE AND USE OF MATHEMATICAL FORMULÆ.

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A MATHEMATICAL formula is a collection of algebraic symbols so grouped as to indicate the law to which are subject the quantities represented by those symbols. If this definition is a true one, it follows that the existence of a mathematical formula without the existence of law, is impossible, or in other words, a mathematical formula is the exponent of law and order. In a universe of chance, mathematical science could not exist. If either in the subtle operations of the human understanding or in the material phenomena of nature, one fact could not follow another in the logical sequence of cause and effect, then it would not be possible to conceive of the existence of the science of mathematics, for such an operation involves the condition that one thought shall follow another in logical order. The very fact then that the human mind is capable of conceiving the idea of the existence of pure mathematics, is proof positive, not presumptive evidence merely, that the operations of that mind are bound by rigid laws. That is, having given the quantities, by their symbols, denoting the effect of the will and subjective impressions of outward things, and the laws showing their relations to each other, then by a mathematical formula the exact result of that operation called thinking, might be at once determined. Of course those quantities and the laws which govern them are of such a transcendental nature that it is absolutely impossible to co-ordinate them; they approach too closely the ultimate nature of the personality of the individual. Considerations of this nature, however, lead to a field of unlimited extent, which may be successfully explored by the human intellect.

We observe the phenomena of nature and at once detect the fact that under equivalent circumstances the same condition, or conditions of things result, and therefore, it may be predicted to a certainty that if the causes represented in a mathematical formula in a manner shown by the laws which govern them, the effect will be indicated with absolutely unerring accuracy. In fact writing the mathematical formula is nothing more nor less than formulating the relation of cause to effect, or *vice versa*.

We are now in a condition to appreciate the value of a mathematical formula considered in itself. In the first stage of a discussion or of an investigation, the mind does establish certain conditions called premises, either by certain fundamental truths called axioms, or by other truths previously determined by a separate line of proof. After having established the premises, however, the operations become too complex for the unaided action of the imagination, and the mathematical formula must be used as the only way out of the difficulty. It takes up the thread of reasoning where the mind leaves it, and follows it through all complications without even the possibility of error. This formula in its primitive condition, gives expression to the premises only. Any subsequent change in the formula, made according to the mathematical axiom that for equals, equals may be substituted, will give a result which can possibly have no property antagonistic to those expressed in the premises or original question. Whatever be the length or the complexity of the reductions made or changes wrought, so long as that axiom is not violated, then there will be in the result no trace of a

property which is not implied in the primitive condition.

In reality a mathematical formula, is the very essence of logic, occupying a position even above and beyond the syllogism.

Contradictions and absurd results cannot, from the very nature of things, exist in a mathematical formula. Results may be, and often are, arrived at which cannot in the present state of knowledge be translated. Quantities are used to which no definite values can be assigned yet they are treated as if they were limitable, and the results obtained commend the most implicit confidence of the mathematician. These characteristics, however, of the science, simply show how absolutely universal and consequently how intensely practical is its application. Those transcendental quantities which are involved in the use of mathematical formulæ, and of a clear conception of whose nature the human mind is not capable, bear about the same relation to finite quantities, that those things which are not seen in the universe hold to things which are; they are the limits toward which the reason may advance, but which it can never reach.

The importance of all these results may not seem very apparent, but it has a very substantial existence nevertheless. It is very true that all reasoning is not conducted by the aid of a mathematical formula, but it certainly is true that it may be, and it is no less true that all reasoning leading to correct results is equivalent to an operation which would be indicated by a formula applying to the case in question. Without the equation as such the science of engineering could not exist, at all. We might have a continuous girder, for instance, but we should never know what load it would sustain; we might infer that there are points of contra flexure and sections of greatest stress, but we should never know where they are. The reason why a mathematical equation is so valuable to us, as engineers, is because the letters in it stand for the things themselves, for forces and dimensions: they are not imaginary things put down on paper for the purpose of giving the subject mysterious surroundings, as is often confidently asserted by ignorant and so-called *practical* men; nor yet is a formula a mere piece of machinery.

Every operation with mathematical formulæ stand for just so much physical reasoning of the highest order, and every formula represents the precise relation in space existing between the quantities under consideration. No formula is thoroughly understood or of any real use to a professional man until these things are thoroughly realized. The correct interpretation of an equation and the discrimination of the proper relation which it holds to his work, are some of the most important duties of the professional man; in truth therein lies the fact that he is truly professional. This point cannot receive too much emphasis. To obtain an equation is one thing, and to understand it is another.

The contempt shown by so-called "practical" men for educated technists and their opinions, is, doubtless, almost entirely based on the fact that the former are incapable from lack of educational training of appreciating the value of a mathematical formula. In fact this distrust of mathematical formulæ is not altogether confined to those who lack scientific training, although it ought not to be found outside of their ranks. The old notion of the antagonism existing between "theory" and "practice," has the same source. It must be confessed that the scientific man himself is too often responsible for this state of things. He proudly points to his formula as the "no-beyond-which;" the authority which is not to be meddled with or questioned under any circumstances whatever; when in reality he utterly fails of his duty. A mathematical operation is not to supplant the reasoning faculties, nor is a formula a blind guide to one's operations, to be used as a dose of medicine is to be taken, trusting that the result will be a desirable one. The most powerful of allies, if intelligently used, becomes a very dangerous thing if handled at random or ignorantly. The meaning of every formula should be interpreted with scrupulous care, for it is the exponent and embodiment of reasoning of absolute accuracy, the very co-ordinating of thought and the determination of one's mental position in regard to the subject that may be under consideration.

For obvious reasons, mathematical work should be as simple as possible. The usefulness of a formula increases

very rapidly with its simplicity. But, on the other hand, when other things are equal, the more profuse a book is in formulæ the more easy to comprehend will it be in the treatment of any given subject. For this reason, the works of Rankine requires the exercise of much more thought than those of Weisbach. Once understood, however, the works of the former possess many advantages over those of the latter.

In the application of a mathematical formula, the greatest care should be taken that the conditions under which it is used are the same as those for which it has been demonstrated. If the dimensions of a girder of uniform resistance be determined in the ordinary manner, such a girder will be a failure, for the formula was demonstrated by ignoring no less a matter than the shearing stress. A confusion of units often vitiates what would otherwise be a correct result. The various steps of a demonstration will indicate whether quantities of the same kind are to be expressed in the same unit or not; but whatever is implied in the demonstration must be used, and nothing else.

The sign of the quantity entering the formula is of no less importance than the unit in which it is expressed.

Leaving the subject as it directly affects us, it may be interesting to take a brief glance at what the elegance and power of mathematical analysis has won for itself in its application to other branches of science.

No less persons than De Gordon and Boole have made successful efforts towards giving the science of logic a thorough mathematical treatment, and it has been put upon a firm mathematical basis by W. Stanley Jevons, of the University of London, one of the greatest thinkers of the age. He does away entirely with the syllogism, by using the simple mathematical axiom, that for equals, equals may be substituted, and actually makes a fallacy impossible.

The same author, Jevons, has gone far toward representing the various quantities which enter into the science of Political Economy by mathematical symbols, and only lacks data, which will be supplied by experience, to make the science capable of exact mathematical treatment.

In various quarters efforts are already being made to reduce chemical reaction to a mathematical basis, and there is the strongest reason to believe that such efforts will eventually be successful.

By one of the most powerful analyses ever made, Helmholtz has shown how the visible universe may have been evolved from a perfect and invisible fluid by certain dispositions and positions of the atoms of such a fluid. In short, as has been said before, whatever operations in the universe are subject to law and order, and there are none other, are capable of being represented by mathematical analysis, though infinitely intricate it may be in many cases.

## IRRIGATION IN SOUTHERN INDIA—THE BASIN OF THE KRISHNA.

From "The Geographical Magazine."

THE catchment basin of the river Krishna includes a great part of the region which has been the principal scene of the recent famine, and over which the rainfall is less than 30 inches in the year. This dry region comprises part of the Deccan, several districts of the Bombay and Madras Presidencies, all within the Krishna system, as well as that part of Mysor within the basins of the Krishna, Kaveri and Pennair. Consequently the waters flowing from the part

of the ghats which overhangs this dry belt have a most important function. Upon its careful storage and distribution depends the existence of the inhabitants of a country 94,500 square miles in extent. For that is the area of the Krishna River basin. The streams whose fountains are in the Western Ghats from about 13° 50' N. to 19° 50' N., a distance of 360 miles, all flow into the Krishna, the length of the main river being 800 miles.

The source of the Krishna is in the

Mahabaleshwar Hills, within 40 miles of the western coast of India, together with those of its tributaries the Koina and Yena. The temple of Maha Deo, at Mahabaleshwar, is built at the foot of a steep hill, overlooking a deep ravine, and has an open space in front. The exterior is faced with pilasters painted yellow, the intermediate spaces being red. In the centre there is an arched door-way leading into an interior cloister built round a tank, into which a stream of water pours out of a cow's mouth. This is the source of the river, considered as the deity in a female form, and often spoken of as Krishna Bai, or the Lady Krishna. Tall trees and bushes cover the sides of the hill, such as roses, daturas, and jambul trees with heads of graceful white feathery flowers. The total rainfall, on these hills, which are only 4500 feet above the sea, is 200 to 220 inches.

Descending rapidly from its source, the Krishna flows past the beautiful city of Wai with its temples, and handsome flights of stone steps, and lovely Brahman women. It then enters the Satara district, and commences its beneficent irrigating work, in the face of special difficulties. The rivers, in the Krishna system within the Bombay Presidency, have so slight a slope that their fall would not gain much on that of a canal, while the steep transverse slopes of the valleys prevent canals from being taken to any distance from their parent streams. The rivers are filled at the time of rains, but during the long dry season of eight months they become mere threads. Here the objects are the retention of supplies of water which run to waste during the rains, and the command of the barren lands on the sides of the valleys. The principal work on the upper part of the course of the Krishna is called the Krishna Canal. A dam is thrown across the bed of the river at Kurvar in the Satara district, provided with scouring and regulating sluices. Thence a canal is taken with a slope of a foot a mile, and a course parallel to that of the river at first, but eventually receding from the bank so as to command a larger area of land, the number of acres irrigated being 1,825. Within the same district the canals from the Yerla, Rewari, Chikli, and Gundauli tributaries

irrigate 997 acres; and the Magni tank and canal works, 348. The canals from the Yerla River alone, if supplied during the dry season from storage tanks, would irrigate the area of 12,000 acres which they command. The projected Nehn Tank will effect this object. It will require an earthen dam 4,400 feet long, with a greatest height of 63 feet. The drainage area above the tank is 60 square miles, and the average rainfall 24 inches. Another scheme, in Satara, is the construction of the Pingli Tank, on a tributary of the Máu River, in one of the driest tracts of the Deccan, with a fall of only 24 inches. A dam 53 feet high will impound 195½ millions of cubic feet of water, and the tank will command 3,000 acres by means of the Gundauli Canal.

From the north the Krishna receives the River Bhima, draining, with its tributaries, the Sina, Nira, and Muta, the districts of Ahmednagar, Poona, and Sholapur. The most important work in the basin of the Bhima is that for the water supply of Poona and Kirki. It consists of a masonry dam of great height and 2,900 feet long, at Kharakwasla, across the Muta Valley, to form a reservoir. Two open ducts lead the water to Poona and Kirki, where the water is distributed by iron pipes. The canals are still under construction, and, when completed, will supply a large area with irrigation. The Ekruk tank, four miles north of the town of Sholapur, is on the Adila, another tributary of the Bhima. The dam across the Adila Valley is 7,200 feet long, and 72 feet high in the center, with a waste weir at the east end. A lake is thus formed, with an area of 6½ square miles, and 35,840 acres are brought under its influence by means of three channels. The dam was completed in 1869.

From the south, and within the Bombay Presidency, the Krishna receives the Rivers Gatparba and Malparba, which drain the districts of Belgaum and Dharwar. The Gatparba has an independent course of 160 miles; and about 35 miles north-east of the town of Belgaum the river drops over a perpendicular quartz rock 176 feet high, forming the beautiful Falls of Gokak. In the rains the river is 180 yards wide, and temples, sacred to Mahadeo, are built on

either side of the cataract. There are several proposals for utilizing the waters of the Gatparba and Malparba, by a canal from the former river at Gokak, by a canal from the Malparba into the Dharwar plains, for completing the Kalhola-nullah, Churdi, and Maddak tanks. But the latter scheme is the only one that has been carried out. Belgaum has an area of 4,592 square miles, and a population of 938,750, or 204 to the square mile. Dharwar, in an area of 4,565 square miles, has a population of 988,037, or 216 to the square mile.

Most of the irrigation work in the Bombay districts within the basin of the Krishna has yet to be accomplished. Many great reservoirs for the storage of water, in this part of the basin, might be constructed, besides those which I have enumerated. For instance, Colonel Meadows Taylor, in his journey to Ahmednagar in 1853, mentioned how much he was struck with the capabilities of the country for large irrigation works, and, in particular, for tanks. Streams descending from the table-lands to the north, and flowing into the Sina, afford ample supplies of water, and the ground, from its peculiar character, provides most convenient basins, only requiring dams to be converted into large tanks. Until all this storage work is executed, the people will be exposed to periodical visitations of famine. It must always be remembered that improved communications can only afford the means of relieving, not of preventing scarcity of food.

After entering the territories of the Nizam, the Krishna leaves the table-land of the Deccan, and falls, by a descent of 408 feet in about three miles, into the lower level of Shorapur. Here, in the floods, there is a magnificent broken volume of water, rushing down an incline of granite with a mighty roar, and a cloud of spray dashing up high into the air. The Krishna then receives the Bhima, its chief northern tributary, and forms the northern boundary of the Raichur Doab, until it unites with its great southern affluent, the Tungabhadra. The country of Shorapur, between the Krishna and Bhima, was the scene of Colonel Meadows Taylor's administrative labors from 1841 to 1853,

and irrigation received a full share of attention at his hands. His first essay at irrigation works was the repair and extension of the lake at Bohnal, and it proved a complete success. He made it into a sheet of water  $2\frac{1}{2}$  square miles in area. His new tank at Kuchaknur, near Bohnal, has an area of  $6\frac{1}{4}$  square miles, and a dam 1,872 yards in length, irrigating 10,000 *bigahs* of rice.

The great southern tributary of the Krishna, the Tungabhadra, has its sources in Mysor. It is formed by the confluence of the twin streams, Tunga and Bhadra, at Kudali, nine miles N.N.E. of the town of Shimoga. It then flows northwards, receiving the rivers Warda, Choardi, and Kumadvati, and, on leaving Mysor, forms the boundary between the Madras and Bombay Presidencies, with the district of Bellari on the right, and that of Dharwar on the left bank. The Tunga, 149 miles long, has a catchment basin of 1389 square miles, of which area the drainage of 100 square miles is intercepted by tanks; the Bhadra, 160 miles long, has the drainage of 175 square miles, intercepted by tanks, out of an area of 1675; the Warda, forty-seven miles long, has the drainage of 180 out of 610 square miles, intercepted by tanks; and the Choardi, forty-three miles long, has the whole area of its catchment basin—510 square miles—fully utilized. The Tungabhadra is never dry, and in the rainy season it swells prodigiously, and forms a rapid and muddy stream, ten feet higher than the rocks which stand out in its bed during the dry season. Its four sources, the Tunga, Bhadra, Choardi, and Warda, drain an area of 3754 square miles in Mysor, chiefly mountainous country, with a rainfall of 135 inches in the year. After the united stream enters the plains, it flows through a region where the rainfall is only twenty-four inches. The ancient name of the river is the "Pampa," by which it is mentioned in the Ramayana. The tradition is that Hiranyaksha, son of the Rishi Kasyapa, seized the earth, and bore it down to the lower world; upon which, Vishnu, assuming the form of the *varāha*, or boar, plunged into the ocean and brought up the earth again. The perspiration arising from this exertion trickled down the boar's tusks, and formed two streams, that from the left

tusk being the Tunga, and that from the right tusk the Bhadra.

In the Bellari district the Tungabhadra has long been used for irrigation. At Desanur and Siragupa there are two *anicut*s, by which 2,519 acres are irrigated. Next come the Valabapur and Korragul *anicut*s, being two branches, with an island between. The former is a reconstruction of an old native work, consisting of loose masses of stone. It is now of solid masonry, with *chunam*, and is 994 feet long. The ancient work was built by Krishna Rayel, the King of Vijayanagar, in 1521 A.D. The Korragul is 400 yards long, of rough native work. Next comes the Ramanagadda *anicut*, across the western branch of the river, opposite the Island of Kuravagadda, and the Kuravagadda *anicut* crosses the eastern branch. The Roya channel is turned out of the river above this *anicut*, and has a tortuous course of 217 miles, ending in the Kamlapur tank. The Bella *anicut* is just above the village of Hosur, an ancient native work, concave towards the stream, only extending from the right bank to an island, and the channel from it is but  $4\frac{1}{2}$  miles long, then dividing into several smaller channels. The Turut *anicut* is taken across the river about a mile west of the old city of Hampi, and is formed of a number of bits of masonry, connecting islands and rocks. The channel from it is very tortuous. The Ramsagra *anicut* is an old, rough stone dam, running diagonally up the river, connecting islands and rocks. Its channel is  $9\frac{1}{2}$  miles long, and tolerably straight. The Kampli *anicut* also consists of detached pieces. The last dam is called Taumbiganur, whence the Rampur channel flows for seven miles. All these *anicut*s, except the new one at Valabapur, were built by the ancient Kings of Vijayanagar. The total length of the nine channels taken from them is  $89\frac{3}{4}$  miles. There are also eight large tanks in the Bellari district, securing cultivation to 29,728 acres.

The Kings of Vijayanagar did all in their power to fertilize the arid region over which they ruled from 1034 to 1524. Abdu'r-Rizzak, the Envoy of Shah Rokh, in 1441, and the Italian Nicolo Conti soon afterwards, visited Bijayanagar, and both describe the magnificence of

this city on the banks of the Tungabhadra, now a silent and desolate mass of ruins. Channels of water flowed through the streets and irrigated the gardens, while the larger channels from the *anicut*s were extensively employed for the cultivation of rice, sugar cane, cocoa nut, turmeric, and especially ginger. Many noble tanks, the largest nearly three square miles in area, were also constructed by the Kings of Vijayanagar. Abdu'r-Rizzak tells us that the country was well cultivated and very fertile, and that the city of Vijayanagar was such that the pupil of the eye has never seen a place like it.

The people of the Bellari district have suffered sorely from the famine, and the English, as the successors of the Vijayanagar Rajahs, are bound not only to maintain, but to extend and complete the irrigation works. The way is clear, and even detailed surveys have been executed by Mr. Gordon. The Bukkachera project would have the effect of irrigating 11,000 more acres. The Ruddam project will add 1344 more, the Hindipur project will secure to eleven tanks a regular supply of water; and the Bom-anahalli project is designed to form a reservoir capable of storing sufficient water to irrigate 64,000 acres. The water is to be distributed by two channels. Then there are the two schemes of the Madras Irrigation Co. which have not yet obtained sanction. The first is for a canal to be taken from the Tungabhadra at Valabapur, to cross the hills near Daroji by a deep cutting and a tunnel 450 yards long, and then to take a nearly straight line to Bellari. Mr. Gordon completed his surveys for this project in 1867, ten years ago. It would have irrigated 150,000 acres. Another project would lead a canal from the Tungabhadra at Hosur, pass round the hills instead of through them, and thence go to Bellari. It is designed to irrigate 212,000 acres. The whole cost of these works would be £950,000, the interest on which at 5 per cent. is £47,500. In 1854 about four times that amount was wasted by hurried expenditure on famine roads, and by remissions, besides the loss to the people of their crops and cattle. These facts speak for themselves. The famines in Bellari are mainly due to the persistent refusals to sanction the

execution of feasible and well-matured irrigation schemes.

An important tributary of the Tungabhadra, coming from the Mysor district of Chitaldrug, is the River Vedavati, or Hagari. It is formed by two streams, the Veda and the Avati, both rising in the Baba Budan Mountains, and has a catchment basin of 2250 square miles, with a rainfall of twenty-four inches. It flows through the central belt of hills by the pass called Mâri-Kanive, and soon after leaving Mysor receives a tributary called the Janagi-halla, or Chinna Hagari. It is a very shallow river, and presents a broad bed of sand in the dry season. The Hagari has a course of 114 miles in Mysor, with a catchment basin of 5,295 square miles, of which 4,097 have their drainage intercepted by tanks, and that of 1,198 is not utilized. The Chinna Hagari is 53 miles long. Out of the 524 square miles of its basin, the drainage of 356 is intercepted by tanks. A number of small channels are drawn from the Hagari, in the Kador district of Mysor; but the great project which would fully utilize its waters is still neglected. This is the construction of an embankment in the Mâri-Kanive gorge, and the consequent creation of an immense reservoir that would irrigate 50,000 acres of the fertile but now arid plains of Hiriyur. At the time of Dr. Buchanan Hamilton's tour in 1800, this Mâri-Kanive gorge, in the Chitaldrug Hills, was pointed out as a spot peculiarly favorable for the construction of a dam. But nothing has ever been done, and this is the more to be deplored because large sums have been spent in surveys and measurements. The whole Krishna system, within Mysor, has a united length of 611 miles, and a catchment basin with an area of 11,031 square miles. Out of this, the drainage of 6,217, or 56 per cent., is intercepted by tanks.

After entering Bellari, there are channels taken from the Hagari which irrigate 1,500 acres; and it falls into the Tungabhadra 72 miles above Karnûl. The Pennair is another river which, though not perennial, brings down large volumes of water with its freshes. It has a course of 100 miles in the Bellari district, and the construction of a few *anicut*s would change the face of the

country. The Bellari district, with an area of 11,007 square miles, has a population of 1,668,006, or 152 to the square mile.

No region in India is more dependent on adequate supplies of water for the existence of its inhabitants than the Ceded Districts of the Madras Presidency; and when the Madras Irrigation Company was formed in 1860, with a capital of £1,000,000, having interest at 5 per cent. guaranteed by Government, the Ceded Districts were selected as the scene of its operations.

The project of this company was partially sanctioned in 1861. It was to divert, by means of an *anicut* at Sankasala, 17 miles above Karnûl, a portion of the flood waters of the Tungabhadra into the valley of the Pennair, through a capacious canal along the right bank of the former river, and across high land, forming its watershed to the east. But the other parts of the project, including the works for irrigating the Bellari district, and the construction of large reservoirs for the storage of water have not been sanctioned.

The refusal to sanction the construction of these reservoirs ensured the failure of the enterprise. From June to November there is abundance of water available from the Tungabhadra, which now runs to waste. But from November to June not a drop can be allowed to be abstracted from that river without injury to the Krishna delta irrigation. Capacious reservoirs for storage were, therefore, essential to provide for the summer supply of water. One would have been in the Mâri-Kanive, another would have been in the Hindri Valley, covering an area of 28 square miles, and another at Kara Bellegal, about 30 miles from Karnûl. Large reservoirs were also to have been constructed at Mudaba, on the Tunga; at Lakkawali, on the Bhadra; and at Masur, on the Choardi. But permission to undertake these absolutely necessary works has been refused.

At Sankasala an *anicut*, 12 feet high and 1,500 yards long, was thrown across the Tungabhadra. From its right flank the main canal is carried parallel to the river for 17 miles, with only one bank, from 16 to 34 feet high, the other being formed by the natural rise of the ground. Thus a quantity of land is submerged,

while the single bank is subjected to violent action from the waves, owing to the extensive spread of water. Close to Karnúl the canal is taken across the Hindri River, on a fine aqueduct. At Metakondal, seventy-two miles from Sankasala, there is a cutting a mile long which takes the canal from the Krishna basin, across the water-parting, into that of the Pennair, descending the valley of the tributary Kolair into the Pennair itself, by a succession of locks, in a fall of 236 feet. The canal is completed from the Sankasala *anicut* on the Tungabhadra to the Pennair, a distance of 143 miles, but not so as to be capable of bearing the full amount of water, owing to weakness of construction. Another defect is, that sufficiency of waterway is not provided for the passage of flood waters, either under the canal or by surplus weirs in its banks, for the escape of storm waters entering it when full.

Water was first admitted into the main canal at Sankasala on the 10th of July 1864. In 1866, the original sum of £1,000,000 having been found insufficient, the Secretary of State sanctioned the addition of £600,000 to the Company's capital, also with a guaranteed interest of 5 per cent., on condition that the canal, as far as the Pennair, was completed by July 1871. By that date the main canal was made, all the sluices in it were built, and the channels for distribution were in progress, 216 miles of them, commanding 91,567 acres, being finished. But if the full amount of water was admitted into the canal the embankments and walls would fail at many places. The total expenditure on the canal, in India, up to 1876 has been £1,583,308. The extent of irrigation in Karnúl was 10,420 acres, and in Cuddapa 5,949 acres, total 16,369 acres; and the whole revenue from irrigation amounted to £5,763. There is no marked extension from year to year, and the financial prospects of the canal are most unsatisfactory, not nearly paying its working expenses. The rate charged for water, namely, 6 rupees per acre, is considered to be excessive, for ryots are unwilling to go to the expense of converting dry land into wet, when they have to pay so high a charge.

The Karnúl district has an area of 7,358 square miles with a population of

959,640, or 130 to the square mile; and Cuddapa covers 8,367 square miles with a population of 1,351,194, or 161 to the square mile.

The Tungabhadra, after a course of 213 miles, falls into the Krishna about 81 miles below Karnúl; and soon afterwards the main river approaches the gorges of the Eastern Ghats. In this part of its course the Krishna receives several small tributaries on its left bank, from that part of the Nizam's territory, which formed the ancient kingdom of Telingana. It is now included in the three zillahs or districts of Nulgunda, Kummum, and Eilgundel, which vie with Mysor and the Carnatic in the number of their tanks. Eilgundel is, however, within the Godavari river basin. A splendid system of tank irrigation was established by the ancient Telugu dynasties, and maintained by their Muhammadan successors. The surface of Telingana is undulating, with numerous hollows and depressions suited for tank basins, and detached granite hills crop out in all directions. The drainage from summer rains is stored in tanks, of which there are upwards of 2,000 in the Nulgunda zillah, and as many in that of Kummum. In many places permanency of supply is maintained by channels drawn from rivers or rivulets on the way to the Krishna. Thus a canal from the Musa, near Haidarabad, fills a series of four tanks, one below the other.

The Krishna and the Pennair, after passing through the Eastern Ghats, supply water for two important systems of deltaic irrigation. The upper courses of these rivers and their tributaries traverse the wide belt of arid region, with a rainfall of less than thirty inches, which is exposed to periodical visitations of scarcity and famine. If the necessary storage reservoirs were constructed on the streams which command this region, so as to supply water in the years when the usual rains fail, there would be no more famine. It is quite true that, even if all water was intercepted and none was wasted, nothing like the whole calculated rainfall could be relied upon. Sir William Denison had a careful experiment made at Sydney, in New South Wales, which showed that not more than a quarter of the total rainfall, on a given surface of an average character, finds its

way to the outfall. Still, after all possible allowances, the existing *data* show that, if no water within the Krishna catchment basin was allowed to run to waste, all danger of a recurrence of famine in that region would be at an end.

Karnúl and Cuddapa are divided from the districts on the east coast by the Eastern Ghats, the highest peaks of which attain a height of 3,000 feet. The slopes are covered with low jungle, in some places mixed with bamboo, and in parts timber of good size is met with. The Krishna passes through this chain, and enters the low country about sixty miles from the sea. Below Bezvara, near the entrance of the gorge, both banks spread out into rich alluvial plains. At Bezvara the River Krishna is 1300 yards wide, and has a depth in the dry season of five to six feet, in average freshes of thirty-one, and in highest freshes of thirty-eighth feet. The flood discharge is 1,188,000 cubic feet per second. The Krishna and Godavari have produced the alluvial plain on this part of the east coast of India, and half-way between them is the Colair Lake, a low swampy tract representing the work which the two rivers have to perform before the alluvial plain can be regarded as perfect.

The English acquired this plain in 1766, and for eighty years they did absolutely nothing, while famine and pestilence periodically desolated the region. In 1833, when the rains failed, not less than 200,000 people died of hunger, the Government lost £900,000 of revenue, and the loss of property amounted to £2,500,000. So that neglect of irrigation works is a most wasteful, as well as a life-destroying policy. By establishing channel heads on the river banks at the apex of the delta, and by securing there such a height of water as the levels of the lands to be irrigated may require, the whole tract below is placed under command, and its productiveness is secured to an extent only limited by the volume of water at command. The Krishna delta works affect an area of 2,000 square miles, inhabited by 1,000,000 souls. The river flows along an elevated central ridge, or backbone, with the country falling off gently towards the right and left, and a general inclination to the sea.

At Bezvara, the Krishna flows between hills, with a width of 1,300 yards. The hills furnish an abundant supply of stone for building, and lime is easily procurable. The position is exactly at the apex of the delta, and the height is sufficient for purposes of irrigation. Here the *anicut* has been thrown across the Krishna. The work was begun in 1852. It consists, first, of a broad basis of heavy stones thrown into the river, and allowed to assume its own natural shape, 3,750 feet long, 305 feet broad, 21 feet high in front, and fourteen feet above the summer level of the water. It is faced with a casing of stone masonry, seventy-five feet broad, resting on a double row of foundation walls. The sill is twenty feet broad and five feet thick, of cut stone, bound together with iron clamps, and 1,280 yards long. Under-slucices are provided at the right and left extremities of the dam, for the purpose of scouring out the silt in front of them, and thus keeping an open channel at the heads of the irrigation lines. The total length of each sluice is 132 feet.

On the Masulipatam, or left bank, the main channel from Bezvara breaks into two branches, 900 yards from the head sluices. One runs towards Ellore, thirty-nine miles long, and the other to Masulipatam, forty-nine miles long. The first branch of the Ellore canal opens at the eighth mile, and is called Ryve's Channel, and a branch, nineteen miles long, runs to Gudaveda. Various other channels spread over the delta, in the direction of Masulipatam. On the Guntur, or right bank, the main western channel runs parallel with the river, with two principal branches at right angles, the Vellatur and the Yeskapilli. The Comamur Channel runs south-west, away from the river, and will irrigate 100,000 acres, in a length of fifty miles. The whole length of the principal canals already finished is 254 miles; when completed their total length will be 320 miles. The irrigated area in the delta is 226,226 acres, yielding a revenue of £89,000.

The river Pennair is connected with the Krishna system by the Madras Irrigation Company's canal, and the two rivers may be appropriately treated of together. The Pennair rises in the north

of Mysor, describes a curve through the Bellari district, flows through Cuddapa, and falls into the sea about nineteen miles below the town of Nellor. Its length is 355 miles, and the area of its catchment basin 20,500 square miles. During the course of ages the Pennair has formed for itself a delta of alluvial soil, peculiarly well adapted for rice crops, in the district of Nellor, the area of which is 8462 square miles, with a population of 1,376,811 souls, or 163 to the square mile. In former times numerous tanks were formed by the natives, to supply water for their crops, and small irregular channels were led off from the river. But in 1855 an *anicut* was constructed across the Pennair at Nellor, in order to secure a good and certain supply of water for all the tanks. In 1857 the flood waters rose to such a height and did such damage that a second dam was built. This also failed, and the present *anicut* designed by Sir Arthur Cotton was completed in 1863.

It is 677 yards long, with the crest nine feet above the bed of the river. Hitherto it has stood admirably. The Pennair comes down impetuously in bursts of short duration, so that with a precarious river of this kind it is necessary to keep a reserve of water by means of the Nellor and other tanks. Thus the system consists of an *anicut* and a series of tanks, water being given direct from the *anicut* so long as there is water in the river. The supply channels are so adjusted as to discharge into the tanks until they are full, and then to supply the land direct. The irrigated area is only on the left bank, the levels on the northern side being too high.

The water supply under command will irrigate 64,000 acres, the quantity allowed per acre being  $2\frac{1}{2}$  cubic yards per hour; and this will be supplied for 150 days, which is ample time for a rice crop to come to maturity. There are three main channels issuing from the primary feeder, called Jaffer Saib's, Krishnapatnam, and Savepalli; under the two first 34,000 acres being cultivated, and under the last 30,000.

There are several more smaller rivers in the Nellor district which can be utilized for irrigation. A large reservoir could be formed near Gandepalem, which would be of immense use to the

people, and where a tank existed in former times. Throughout Nellor there are 975 tanks, yielding a revenue of £94,000, fed by small rivers and streams which rise in the Eastern Ghats. During the recent famine, one of the suggested relief works was the Sangam project for using the flood water of the Pennair. The head works are at Sangam, near Atmakur, and about thirty miles above the *anicut* at Nellor; and their object is to carry water to tanks and reservoirs for irrigation, by which 94,000 acres would be brought under wet cultivation.

The extension of the irrigation works connected with the Krishna and Pennair, and their tributaries, involves questions which touch the interests of by far the largest part of the arid country recently visited by famine. The complete utilization of all the water within this area would be the cause of a great and beneficial change in the physical aspect of a vast region. Such a change, by following in the footsteps of the ancient rulers of the land, the Kings of Vijayanagar and Telingana, it is the obvious duty of the English masters of India to effect.

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At the recent meeting of the American Association for the advancement of science, Prof. Grote, of Buffalo, described a new enemy of the pine tree which he had observed. During June and July the red and white pine trees show by their pitch exuding that they are attacked by an insect. The wounds usually appear on the main stem below the point where a branch starts. On cutting into the bark, the larva will be found which has caused the injury. The length of the larva when full grown is three-quarters of an inch. It makes furrows by eating on the inner side of the bark, producing bleeding, which sometimes kills the tree, and is always injurious. In July the worm spins a whitish gray cocoon within the exuding pitch, and the moth comes forth in 10 or 14 days. It has been found in the Scotch, Austrian, and Russian pine as well as in our native varieties, and seems likely to prove a formidable enemy to the cultivated pine in general. The only remedy yet devised is to apply the knife and cut out the larva.

## MOMENTUM AND VIS VIVA.

By J. J. SKINNER, C. E., Ph. D.

Written for VAN NOSTRAND'S MAGAZINE.

In the last number of this Magazine Prof. De Volson Wood makes some comments on my previous series of articles under the above title, which seem to require some examination by me. At the top of page 34 he gives the equation

$$F = Mf,$$

and says that I propose to call the second member of this equation *tend*. This is a mistake. I simply proposed to use the word *tend* to denote the  $\frac{1}{32.1912}$ th part of a pound pressure, which is not by any means the same thing as the second member of the above equation.

Prof. Wood objects to the introduction of three more *abstract terms*. To which I reply that if the words *pound* and *ounce* are abstract terms, then the words *matt* and *tend* as I proposed to use them may be abstract terms, and not otherwise. Prof. Wood then quotes from me as follows: "As to practical convenience there may sometimes be advantage in using this unit of force." He adds, for himself, "Now I remark that it is absolutely necessary that it (*the absolute unit*) should be used;" concerning which I will say that different nations use different "absolute" units, if they use any; and my illustration as to "practical convenience" had distinct reference to only one of these. No philosopher is *absolutely* required to use that one, if he prefers the German or the French or any other unit, *absolute* or arbitrary.

On page 35 Prof. Wood inquires, "What are the effects of force?" and answers, "One of its effects is to produce pressure between two bodies; another is to produce motion; another to do work; another to produce energy." May I inquire whether *motion* of masses can be produced without doing *work*; or whether *energy* can be produced without the performance of *work*?

A few lines further on Prof. Wood says of me, "That writer further adds: 'It seems to me that we need in mechan-

ics a name which shall apply to the *exertions of a force during time*, whether this produces apparent motion of masses or not." I discovered too late for correction that the printer had made one error in my sentence, and Prof. Wood's quotation has added another. I wrote, *exertion of force*, instead of *exertions of a force*. Prof. Wood then inquires, "What is meant by a *force* acting during time without producing motion?" But this is not my phrase. My qualifying clause was, "whether this produces *apparent* motion of masses or not." In this clause I meant simply to provide for such a case as for example the action of gravity on a heavy body apparently held at rest by a support. Prof. Wood wants to know whether mere pressure exerted during time is any thing but pressure. I should be as glad as he would be to get a good answer to this question, but I confess I do not know what the ultimate nature of *pressure* is. For all we know, *pressure* may be the result of impacts of etherial or ultra-etherial atoms. If it were so, the sum of all these actions on a particular mass of gross matter during a particular time, might be regarded as a definite quantity of *toil*, although the mass of gross matter should *apparently* remain at rest and therefore not acquire any *momentum*. If pressure were simply the result of such impacts as suggested, I should also be wrong in saying that a pound pressure did not necessarily involve the idea of motion.

Prof. Wood says he is unable to determine my position, and quotes what he seems to regard as self-contradictory statements. I confess that I said at the outset of my series, "*If momentum is a quantity of motion it certainly cannot be 100 pounds;*" but as I went on at some length to show that I did not regard momentum as properly a *quantity of motion*, there was nothing illogical in my afterwards maintaining that under a certain condition the proper unit of the product  $MV$  is a pound pressure.

Again, Prof. Wood says: "I would infer that Professor Skinner claims that momentum is pounds of pressure." I think no one can properly infer this from my series of articles, without also knowing that I expressly state the condition under which alone this is correct. See p. 132, Vol. XVII, 1st col. near foot, *et passim*. And see also foot note, p. 498.

My distinction between *momentum* and *toil*, if both words were to be employed, would be analogous to the distinction between *vis viva*, (or *energy*), and *work*, as explained on page 501 of last volume. I do not think the introduction of new words tends to confusion, if different ideas have been denoted heretofore by a single word whose meaning has had to be made out by the context.

Prof. Wood seems not unwilling to retain the expression *quantity of motion*, and asserts that *quantity of motion* is *momentum*; also on p. 36 he says, "*the unit of momentum will be one pound of mass moving with a velocity of one foot per second.*" But on p. 137, Vol. XVII, I offer against such a conception an argument which seems to me still valid.

In the last lines of p. 36, Prof. Wood says that he understands me to desire to show that *momentum* must always be considered as positive,—that there is no negative momentum. Such an understanding, or misunderstanding, of my desires seems to me strange, in view of the first three lines of p. 237, vol. XVII, and the distinction made on the same page between *arithmetical* and *algebraic* momenta, together with the demonstration that I had given on p. 236 of the fact that the algebraic total of momentum is unchanged by impact, whether the direction of motion is changed or not. There is fallacy or confusion in an argument or two on p. 236, and I took pains to suggest as much on the same page, saying that "we are inevitably led into all sorts of such *absurdities* if we attempt to consider momentum as a quantity of motion;" and I could easily have pointed out just where the fallacy entered, except that I did not think it worth while.

With regard to my expression "an actual increase of momentum by impact, I hope I only need to suggest that I used the word *actual* to mean no more than *arithmetical* as distinguished from *alge-*

*braic*. See 4th line, col. 2, p. 237, &c. I do not hold, and have never maintained that by giving contrary algebraic signs to motions of opposite directions an algebraic increase of momentum could result from impact.

There is, however, this that I may say with regard to my illustrations of the change of direction of motions by a fixed spring or by a semi-circular arc, viz., that I do not deny an effect upon the earth by such change of direction; but, since we know nothing whatever about any material point which is at absolute rest, we are constantly obliged to assume points of reference which shall for argument be regarded as fixed, although they may not in reality be so. If the algebraic as well as arithmetical momentum of two masses could, by impact and a subsequent change of direction of one of them by a simple intervention of human intelligence, be increased with reference to a point fixed relatively to the observer, this might be of interest to him although the algebraic sum total of the momentum of the universe should remain unchanged. It may perhaps be a question whether the algebraic sum of the components of all the momenta of the universe resolved parallel to any given line, is not, with reference to a point absolutely fixed, simply zero.

Prof. Wood calls attention to my applying the phrase *potential energy* to the quantity  $\frac{1}{2}MV^2$ . I know that this energy is usually called *kinetic* and in the offending sentence I might perhaps as well have omitted the word *potential*; but since this energy can be regarded as stored up, or accumulated, by a body, and is not to be exerted for any time, however long, unless some reduction of velocity is produced, it can, in a sense not technical, be regarded as potential.

I believe any one who has attempted to think or write on this general subject will admit that it is a difficult one to treat controversially with perfect freedom from error. In my discussion I can hardly hope to have made no slips, but we, none of us, like to have our work made to appear more unworthy than it really is.

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An important discovery of coal is reported to have been made at South Creek, New South Wales.

## ON THE CONSTRUCTION AND WORKING OF NARROW-GAUGE AND OTHER SECONDARY RAILWAYS.

By JULES MORANDIERE.

From "Mémoires de la Société des Ingénieurs civils," translated Abstracts published by the Inst. of Civil Eng.

THE object of this Paper is to collect together the statistics and other information relating to the present position of these railways, the extent of which in each country of the world may be seen from the figures in the following table (A) :

Name of Country.	Number of Miles.	
	Open to Traffic.	In Construction.
Great Britain.....	26	—
France.....	43 $\frac{3}{4}$	89 $\frac{1}{2}$
Algiers.....	20 $\frac{1}{2}$	155 $\frac{1}{2}$
Belgium.....	77	—
Norway.....	192 $\frac{1}{2}$	—
Sweden.....	163	—
Russia.....	208 $\frac{1}{2}$	—
Austro-Hungary.....	52 $\frac{3}{4}$	18 $\frac{3}{4}$
Prussia.....	20	—
Italy.....	7 $\frac{1}{2}$	—
Island of Sardinia.....	18	—
Switzerland.....	22	—
Greece.....	5 $\frac{1}{2}$	—
Portugal.....	—	—
India.....	820 $\frac{1}{2}$	1,902
Australia.....	328	—
New Zealand.....	244	—
Cape of Good Hope....	67	—
Canadian Dominion....	457	373
United States.....	2,040	7,552
Central America.....	37 $\frac{1}{4}$	155
Venezuela.....	—	—
Peru.....	17 $\frac{1}{4}$	—
Chili.....	118	—
Bolivia.....	—	155
Brazil.....	20	411
Havana.....	—	—
Java.....	34	—

The above table shows that, during the last few years, the number of narrow-gauge lines has increased enormously. The writer is not of opinion that their adoption in France would be advisable, excepting under special local conditions, and thinks that it would be preferable to retain the ordinary gauge of 4 feet 8 $\frac{1}{2}$  inches even for the railways of secondary importance, in order to avoid changes of carriages and wagons, but the narrow gauge is advantageous in

new countries where the object is to obtain the greatest possible extension of railway communication with a limited amount of capital, and for local purposes, especially for the carriage of mineral or agricultural produce, provided that it has not to be subsequently transferred to the wagons of another railway.

A second table shows the names, lengths, gauge, weight of rails, cost of construction, &c., of the principal narrow-gauge railways in the different countries of the world.

In the following short description of some of these, the four first are laid upon or parallel with turnpike roads :

*Lagny to the Stone Quarries of Neufmoutiers and to Montcerf* (France). This railway, 9 $\frac{1}{4}$  miles in length, was originally constructed for the carriage of stone only, but afterwards, at the solicitation of the neighboring towns, passenger carriages were added. It is only seventeen miles from Paris, and is frequently visited from thence as a specimen narrow-gauge line. It runs parallel to the high-road, from which it is separated by a ditch, and this allowed of much economy in the purchase of land. The gauge is 3 feet 3 $\frac{1}{2}$  inches (1 meter) between the rails; weight of rails thirty-two pounds per yard; sleepers two feet six inches apart; width of banks at formation-level nine feet ten inches. The locomotives have six coupled wheels, and weigh, including water and coal, from thirteen to fourteen tons. There are carriages for first, second, and third class passengers, the first with eighteen and the third with twenty-four seats. An extension of five miles to Montcerf remains to be finished.

*Turin to Rivoli* (Italy).—This railway, 7 $\frac{1}{2}$  miles in length, runs along the side of a broad avenue, and connects Turin with the suburbs. The maximum gradient is 1 in 60; the gauge is two feet 11.4 inches (0.90 meter) between the rails; the weight of the rails is forty-three pounds per yard; the sleepers are two feet eight inches apart. The loco-

tives have four coupled wheels, and weigh about eleven tons. The carriages are very small, and only allow of three passengers being seated abreast. The average speed of the trains is  $12\frac{1}{2}$  miles per hour.

*Lausanne to Echallens* (Switzerland).—This railway, ten miles long, is only built on the turnpike-road for a certain distance, and for that length it has been necessary to widen the road by about six feet in order to leave a clear eighteen feet for the ordinary traffic. There is one curve of sixty-six yards radius and nine of 110 yards; the maximum gradient is 1 in 25 for a distance of 660 yards. The gauge is three feet  $3\frac{1}{2}$  inches (1 meter). The weight of the rails is fifty-eight pounds to the yard. The stations consist of two small rooms connected by a third, which is open on the side facing the railway, and they are constructed of wood. There are two locomotives, one weighing fourteen, the other eight tons. The speed of the trains is  $12\frac{1}{2}$  miles per hour.

*The Broekthal railway* (Rhenish Prussia) is twenty miles in length, of which fourteen miles are on a road and six miles in the ordinary way through fields, &c. It was constructed at a total expense of £1,722 per mile; viz., for permanent way, &c., £18,140; for a bridge over the river Sieg £3,540; for stations £5,765; for rolling stock £4,900; for stores, &c. £2,105; making a total of £34,450. A local subvention of £9,000 was granted to the company. The gauge is two feet seven inches.

*The Rochebelle railway*, with a length of one mile 290 yards, carries coals exclusively. The maximum gradient is 1 in 56 for 534 yards; the minimum radius of curve is sixty-six yards. Very small locomotives are used, which draw twenty empty wagons up the incline; the average speed is  $8\frac{1}{2}$  miles per hour. In 1873, 60,000 tons of coals were carried at an average cost of  $5\frac{1}{2}$ d. per ton per mile.

*The Mokta-el-Hadid railway* (Algeria) is  $20\frac{1}{2}$  miles in length, and connects the mines of that name with the seaport of Bona. The gauge is 3 feet  $3\frac{1}{2}$  inches; minimum radius of curves 257 yards; maximum gradient 1 in 117. The original iron rails have been taken up, and the line has been relaid with steel rails weighing forty pounds per yard. The

sleepers are two feet six inches apart. Cost of permanent way per yard with iron rails £1 5s.; ditto with steel rails £2. The weight of the locomotives (with six coupled wheels) is sixteen tons (empty), that of the wooden wagons 1 ton 18 cwt.; that of the iron wagons 2 tons 2 cwt. The rolling stock consists of six locomotives and two hundred and twenty-five wagons. Seven trains, each of forty wagons, run daily in each direction; average speed  $10\frac{1}{2}$  miles per hour.

In Norway six narrow-gauge railways, with a total length of  $192\frac{1}{2}$  miles, have been opened for traffic, and a further 200 miles are in construction. They are all passenger lines, and have been built by the State. The rails weigh from thirty-five to forty pounds per yard. The gauge is three feet six inches; the minimum radius of curves is 200 yards; the maximum gradient is 1 in 45; the average speed is  $12\frac{1}{2}$  to  $15\frac{1}{2}$  miles per hour, including stoppages, that of express trains is  $18\frac{1}{2}$  miles per hour. In 1871 the average gross receipts on 144 miles were at the rate of £218 per mile per annum, and the net receipts £45 per mile.

In Sweden fifteen short lines, making a total of 480 miles of narrow-gauge railways, have been built by private companies, and 150 miles are in construction. Five different gauges have been adopted, varying from two feet seven inches to four feet. These lines have cost from £1,900 to £3,200 per mile; the average speed is under fifteen miles per hour. The rails weigh twenty to forty-five pounds per yard.

The system has been adopted in Sweden of building second-class railways with the ordinary gauge of 4 feet  $8\frac{1}{2}$  inches, and with light rails weighing from forty to sixty pounds per yard. About 590 miles of such railways have been opened to traffic, and 1,140 miles are in construction. They answer very well. Their average cost, including rolling stock, is £6,400 per mile.

In Russia the railway from *Vierhovie* to *Livny* ( $38\frac{1}{2}$  miles) and that from *Novgorod* to *Tschudowo* ( $45\frac{1}{2}$  miles) have been constructed with two feet six inches gauge. The first has a viaduct over the river Linbovsha, which is 420 feet long, and the gradients rising from this point are 1 in 8 for 7,000 yards in

one direction, and for 9,590 yards in the other. The weight of the rails is forty-five pounds. The rolling stock of the Livny line consists of two ordinary locomotives, five Fairlie engines, seventeen passenger carriages, and two hundred and sixty-six goods wagons. The same gauge of two feet six inches has been used on 125 miles of other lines in Russia. They have cost on the average (including rolling stock) at the rate of £6,000 per mile.

In Austro-Hungary gauges of three feet  $1\frac{1}{2}$  inch, 3 feet  $3\frac{1}{8}$  inches, and 3 feet  $7\frac{1}{2}$  inches have been used on six short lines.

In Switzerland the meter gauge has been adopted on three short lines, and the 2-foot  $5\frac{1}{2}$ -inch gauge on a fourth.

In British India 820 miles have been opened to traffic, and 1,900 miles remain to be finished. The gauge is 3 feet  $3\frac{1}{8}$  inches; the weight of rails forty pounds to the yard. Six-wheel locomotives, weighing from twenty to twenty-two tons, are used. The passenger carriages are made with double sides, and at about one foot above the ordinary roof they have a second roof, which projects considerably beyond the lower one to keep off the sun's rays. The first-class carriages are comfortable saloons fitted for seven passengers, and with sleeping accommodation for five. At one end is a retiring room, with washing and toilet arrangements, and at the other a compartment for servants. The cost per mile has varied from £1,088 to £11,392, but the average (including rolling stock) appears to have been about £6,000 per mile.

In Queensland (Australia) 300 miles of railway, with a gauge of three feet six inches, have been opened to traffic. The weight of the rails is forty pounds to the yard. These lines have cost from £4,600 to £11,500 per mile.

In South Australia twenty-eight miles, with 3-foot 6-inch gauge, have been constructed. The weight of the rails is forty pounds.

In New Zealand, the same 3-foot  $7\frac{1}{4}$ -inch gauge has been adopted on 244 miles.

At the Cape of Good Hope sixty-seven miles have been constructed, also with a 3-foot 6-inch gauge. Several hundred miles are in course of construction.

In the Dominion of Canada the same gauge has been adopted on 457 miles of completed railway, whilst a further 373 miles are in course of construction. The average cost per mile of the Toronto-Bruce and Toronto-Nipissing lines, including rolling stock, is stated to have been £3,008; only £448 and £608 per mile on the two lines respectively being charged as expended on rolling stock.

United States of America. A separate table is attached to the original, giving the names and length of sixty-four narrow-gauge railways in the United States, of which  $2,039\frac{1}{2}$  miles were, on the 1st of July, 1874, open to traffic, and 7,552 miles in construction. The most important of these is the Denver and Rio Grand railway, of which at that date  $161\frac{1}{2}$  miles were finished, and 870 miles in construction. The gauge is three feet; the weight of the rails thirty-three pounds. The first seventy-five miles cost at the rate of £3,000 per mile, but the remainder, being over rougher ground, has cost £4,000 per mile. In 1873, on 118 miles, the gross receipts averaged £13 per mile per week; the working expenses £6, and the net receipts £7. The rolling stock resembles that on other American ordinary gauge railways; but some Fairlie engines with twelve wheels, and weighing twenty-six tons, have been adopted. On the Arkansas Central and some other American lines the gauge is three feet six inches.

In Costa Rica (Central America) a 3-foot 6-inch gauge has been used on a line now in construction from the capital, San José, to the Port on the Atlantic. The rails weigh 42 pounds to the yard;  $37\frac{1}{4}$  miles are in traffic, and  $155\frac{1}{4}$  in construction.

In Peru a 2-foot 6-inch gauge has been adopted on the Patillos line, the object of which is to carry nitrate of soda from the interior to the coast. The weight of the rails is thirty-five pounds. This line has some steep gradients of one in twenty-eight, and Fairlie engines, weighing twenty-six tons, are used.

It is stated that the latter run on ten other railways. It results from the data supplied in this Paper that the constructors of narrow-gauge railways have adopted almost every conceivable variety of gauge between 1 foot 6 inches and 4 feet. The following twenty varieties

will be found in Table C, viz: 1 foot 6 inches, 1 foot 11½ inches, 2 feet 3½ inches, 2 feet 5½ inches, 2 feet 6 inches, 2 feet 6½ inches, 2 feet 7 inches, 2 feet 7½ inches, 2 feet 11½ inches, 3 feet, 3 feet 1½ inch, 3 feet 1¾ inch, 3 feet 3 inches, 3 feet 3½ inches, 3 feet 6 inches, 3 feet 7½ inches, 3 feet 7½ inches, 3 feet 10½ inches, 3 feet 11½ inches, 4 feet.

Some information is supplied in

reference to tramways, especially those in Belgium, and the Author recommends particularly the mode of laying and the description of rail employed on the Liege tramways. Also a large amount of further interesting information on the subject of economical railways generally is contained in the Paper, which the limits of an abstract will not allow of being reproduced.

## CHAIN TOWING ON THE ELBE.

Translated from "Revue Industrielle."

THROUGHOUT the navigable portion of the Elbe, from Aussig in Bohemia to Hambourg, the system of chain towing is employed.

The ordinary steam-tugs being unable to compete with the railway, and the towage on the Seine and other French rivers having yielded such good results, M. Nobiling made a special examination of the systems already at work. He found on the Seine a towing system, having a fifty horse power engine hauling a dozen barges, carrying a total load of 3,000 tons at a velocity of 3,200 meters (2 miles) per hour against a current having a velocity of 4000 meters (about 2½ miles) per hour. The system furthermore presents the advantage of producing no waves, an advantage that extends to the maintenance of landings, bath-rooms, rafts, etc.

The Navigation Co. of Hambourg-Magdebourg, having obtained a *concession* for thirty years, selected for their preliminary experiments, a portion of the river between Buckau and Neustadt, about 4,800 meters in length, and where the steam tugs worked with difficulty when the river was high. The chain was established between these two cities, and a flat-bottomed tow-boat, constructed in the work-shop of the Company began a regular service in August, 1866. It was attended with complete success.

The chain was then extended to Ferchland, 48 kilometers below Magdebourg, at a cost of 254,625 francs for the chain, and 264,375 francs for three tow-boats; a total of 519,000 francs (\$103,800). This proved so remunerative that the

Company decided to extend their work to Hamburg, in order to secure the traffic which amounts annually to 300,000 tons. The remaining 158 kilometers were completed in 1874 at a cost of 3,250,000 francs (\$650,000) including a set of ten tows in service.

From 1869 to 1871, 320 kilometers of chain had been established in the upper portion of the Elbe, not including 22.4 kilometers in the Saale, one of the branches of the Elbe.

The total length now of chain in this system is 672 kilometers (418 miles) and the number of tows is 25.

It is estimated that in the old tug-boat system there was a loss of sixty to seventy per cent. of the useful effect, because the force was exerted against a mobile fluid, a loss which is avoided in using the chain.

Where the current is feeble, a single winding drum of large size is sufficient, the chain being held against the drum by two rollers on the lower side; and the chain is further prevented from slipping by a notched groove in the drum which receives the links of the chain. Against rapid currents, or in case of heavy towage two drums are necessary, and four or five turns of the chain about each.

The duration of a chain on the Elbe is about twelve years. The wear is experienced in slipping while passing from one drum to the other. The most frequent breakages have occurred when winding the chain for the first time.

In boats furnished with two drums, the latter are placed centrally, one behind

the other. When there is only one drum, it is upon the side.

It is estimated that this system of towage utilizes eighty to eighty-five per cent. of the power of the machines, and that the consumption of coal is only one-fifth of that of the side wheel tow-boats.

The buoyed chain in the Elbe is an English navy chain of the best quality and of ordinary dimensions; the length of the link being  $4\frac{1}{2}$  times the diameter of the iron; which for the Buckau-Wittemberg section is 22 millimeters, and weighs 1.1 kilos. per meter (21 + lbs. per yard). From Wittemberg to Hambourg, the diameter is 25 millimeters, and the weight is 15 kilogrammes per meter. The chain employed on the Seine has a diameter of only 16 millimeters, a size that would not serve against the swifter currents of the Elbe.

The two extremities of the tow-boats are alike, and are equally furnished with a rudder. The steering wheels are both in the middle of the boat, so that a single helmsman performs the steering, and is conveniently near the machine-room at the same time.

The dimensions adopted are as follows: length 42 to  $45\frac{1}{2}$  meters; breadth 7 to  $7\frac{4}{10}$  meters; depth at center  $2\frac{1}{10}$  meters; draft  $\frac{4}{10}$  meter. Boats drawing less water do not give so good results. They are constructed mostly of boiler plate iron, having a thickness of  $6\frac{1}{2}$  millimeters for the sides and 12 millimeters for the bottom. Latterly, pine of 100 millimeters (4 inches) has been employed for the flooring, and for the bottom oak planking of the same thickness. It is found that wood suffers less than iron when it encounters a pebbly bottom.

Upon the Upper Elbe the tow boats are furnished with two boilers, while on the lower Elbe they have but one. The boilers are horizontal and are designed to furnish 60 to 80 horse-power working at a variable pressure of 5 to 7 atmospheres.

The power is transmitted to the drums by a system of gear wheels. The drums admit of five turns of the chain and a brake. The diameter of each drum is  $1\frac{1}{10}$  meters, and as the velocity is about 60 revolutions per minute, 210 meters of chain per minute pass over the drum when descending, and about 114 meters

when ascending the current, giving theoretical velocities respectively of 12600 and 6840 meters per hour, but which are really 9600 and 4800 meters.

Sometimes as many as thirty pinnaces have been towed at once upon the upper Elbe; the mean number is from four to eight barges. The toll paid is according to tonnage and distance.

There are twenty-five stations on the upper Elbe and twenty-four on the lower. Between certain stations where the towage is difficult the tolls are somewhat increased.

The section between Buckau and Newstadt pays good dividends. Three thousand boats carrying a total of 150,000 tons have passed over this section annually, and have afforded a revenue of 7 or 8 per cent on the original capital.

Upon the lower Elbe the results have not been so favorable, in consequence of an increase of the rates.

The number of days of service of the system has been during four years:

In 1872	....	303 days.
1873	....	340 "
1874	....	293 "
1875	....	259 "

being an average of 300 days.

The distance between Magdebourg and Dresden is accomplished in 72 hours by the chain, but requires 120 hours by the tug-boats.

The boats carrying merchandise are of three classes according to tonnage; they are of 150, 300 and 400 tons burden. The larger ones are the more economical, as is proven by the following figures which exhibit the cost per ton to the company of the transportation both ways between Hambourg and Dresden:

	150 tons	300	400
Going up . . . .	14.37 f.	12.24 f.	11.66 f.
Going down . .	5.47 f.	4.01 f.	3.49 f.

F. PERRIER has, according to the *Comptes Rendus*, made a comparative study of day and night observations, from which he concludes "that azimuthal observations by night possess a degree of precision at least equal, if not superior, to that of observations by day." He will make a special study of the effects produced upon the azimuthal measures by the torsion of the wooden signals under the direct action of the sun's rays.

## THE STATUS AND PROSPECTS OF ENGINEERS.

BY GRAHAM SMITH, A.I.C.E.

GENTLEMEN,—It is now two years since you conferred upon me the honor of allowing me to address you as your president. You will remember that on that occasion my remarks were confined to the importance of societies established on a basis such as ours. This evening I purpose touching upon a somewhat wider subject, and one on which a variety of opinions and notions exists, namely, "The Status and Prospects of Engineers."

A few lines from a "leader" which appeared in the *Scotsman* convey some idea of the public opinion concerning our profession. They are as follows :—"The most observant of country readers will have often noticed that whenever any particularly magnificent or rather astonishing announcement is made, such as a proposal to bore a hole through the earth, or swing the moon round in time to get a shower for the early turnips, the proposer of the said scheme always signs himself C. E. That symbol is the badge of perhaps the most remarkable class of men on the face of the earth. Their progress, like that of the Prussians, has been gradual, yet ceaseless, and has been too little attended to by their neighbors. From small beginnings they have grown so that nothing is too big for them to handle. We may premise that they are a most respectable class of men. They generally sport white vests with adequate coat and continuations, and have an aristocratic look about them. At the same time it is aristocracy tempered with science. They bear themselves with a certain conscious dignity, as becomes men who have taken more liberties with our planet than their neighbors dare to do. In fact, a noble pride, made nobler by humility, is the chief ethical characteristic of the civil engineer. He has a right to be proud. Look at what he has done—what railways he has executed; what harbors he has built; what canals he has dug out; what big ships he has launched broadside foremost, in defiance of all the old women and common sense of the community!"

\* Address delivered before the Liverpool Engineering Society.

It is true that the scientific progress of the profession has been gradual and ceaseless, still the ancients executed works of even greater magnitude than those undertaken at the present day. Lake Moëris was a vast reservoir constructed to impound the flood waters of the Nile, which were afterwards used for irrigation. It had an area of 150 square miles, and the wall or dam which retained these waters was sixty yards wide, thirty feet high, and its site may be traced for a distance of thirteen miles. The pyramids of Gizeh, constructed 5000 years back, and the causeways of solid granite which were laid down to facilitate the transport of stones, often hundreds of tons in weight, were works of vast magnitude. The causeways no longer exist, but Herodotus, who saw them, considered them even greater works than the pyramids themselves. The masonry of these works, and the lifting and transport of the huge blocks, could only have been performed by large armies of men, directed by competent leaders who must have possessed a considerable knowledge of the properties of materials, and must have had a true sense of the simple elements of mechanics.

The profession is undoubtedly of ancient lineage. Tubal Cain was a worker in metals. Dr. Lepsius states that a Royal High Architect of the Dynasty of the Psammetici has sculptured his pedigree of twenty-three generations on the rock of one of the most ancient quarries of Egypt. George Smith, the great explorer of the ancient East, found by an inscription that the title of "Master of Works" existed in Assyria 2500 years back. The remains of canals, aqueducts, reservoirs, and other works are to be found in Egypt, India, China, and, in fact, all over the world, clearly denoting that the ancients possessed men answering to the description and filling the position which the engineer of the present day occupies. The engineer of the ancients was a man of distinction, appreciated and favored by kings and rulers. His works were

held in estimation, for among the titles of the God Vul were those of "Lord of Canals" and "The Establisher of Irrigation Works."

At the present time the leaders of the engineering profession are totally unrecognized by the British Government. On state occasions the merest subaltern in the army takes precedence of engineers, whose energy, ability, and perseverance have been, both directly and indirectly, to no small extent instrumental in placing Great Britain on the high pinnacle upon which she now rests. Patronage has a tendency to enfeeble its recipients; and even were this not the case, engineers are able to dispense with it. Bearing in mind Wordsworth's ideal of manly dependence and manly independence, they steer their own course and assume their own position. All that the profession in general requires is a fair field and no favor, which our Government does not see fit to accord to it in a country like India.

Although titles may be showered on corporate dignitaries and the members of other professions, they are sparsely distributed in that of the engineer, but, excepting as a means of rendering him of increased usefulness, he ought to care little about them. By his own work he may gain more distinction and honor among the inhabitants of the civilized world than it is in the power of all the crowned heads of Europe to bestow. There is no royal road to eminence for the engineer; his honors are alone to be attained by hard work, and cannot be bought at any price. He is yet entitled to have high aspirations as a benefactor of men, among whom he must occupy an enviable position, for his profession implies the possession of the art of controlling the force of the winds and falling waters, so that they may be made to grind corn and weave cloth—to feed and clothe the man; the making and perfecting of machinery for the purposes of cultivation, and the construction of roads, railways, canals, and bridges for the collection and distribution of the products of the earth; the construction of docks and harbors for the convenience and safety of ships bringing raw materials from foreign lands to provide employment for millions, and carrying back the products of vast industries; the ven-

tilation, warming, and draining of the habitations of these people, and the bringing of the pure water of the mountain rill to their very feet; the inventing and perfecting of machinery with which to mine into the bowels of the earth for hidden treasures, and render them convenient for the uses and wants of mankind; and the performing of a multitude of other useful offices much too great to now mention. Thus it is evident that the civilization, welfare, and advancement of nations are to no small extent dependent on the work of the engineer.

It is asked on all sides, what are the prospects of gaining distinction in this vast field of usefulness? In the first place, a man must have ability and training to do his work; and in the second place, he must love it, or the disappointments and hardships which he will have to encounter during the early part of his professional life will possibly cause him to under-estimate his capacities, and render him wanting in self-reliance and decision of character. Nevertheless trials are almost necessary to the proper development of an engineer, just as iron must pass through the fire before it is converted into steel. It is not in the power of every man who enters the profession to become distinguished. Still, if a man of average ability starts in life with a fixed purpose and works determinedly with his whole heart, hands, and brain, asks few favors, and relies on his own labors, he has good prospects of attaining that object.

It is undesirable to have firmness of purpose without sound judgment. In early life it is always better, therefore, to lean to some extent on the judgment of men who are known and tried, and to work cautiously on one's own ideas until the judgment has been educated and its correctness has been repeatedly tested. An engineer having proved himself by self-examination and repeated trial to have a tolerably sound judgment, should then ask advice of those only who are so far interested in his welfare as to trouble themselves sufficiently with his affairs to be in a position to give judicious counsel. Having, with the aid of such few friends, matured measures, they must be fearlessly carried out under the banner bearing the device "I dare do all that may become a man."

He who carries through whatever he undertakes is on the road to making a reputation. Yet it is necessary to be careful, not to promise too much, and to ascertain that the elements of success attend the proposed work, before embarking one's energies in the undertaking.

The friends of the merest tyro in engineering will tell you that he is possessed of talents and genius; and when these are combined with vigor, what may not an engineer achieve in his life? It has been said—"He who in a given time can produce more than many others has vigor; he who can produce more and better has talents; he who can produce what none else can has genius." Now, so long as the major part of the members of the engineering profession possess these qualities, it is safe from falling into the condition of the land portrayed by Goldsmith

"To hastening ills a prey,  
Where wealth accumulates, and men decay."

The profession is quite safe for the present from the baneful influences of riches, and, so long as the supply of men lasts who are competent and willing to do professional routine work for the present scale of remuneration, it can never be looked upon as a means of amassing wealth. Notwithstanding the railway mania, and the great demand for machinery and engineering work during the past half-century, few men have made large fortunes by engineering pure and simple.

Instances are not wanting where young engineers in charge of works have received smaller salaries than the foremen masons and other craftsmen working under their direction. Public bodies seem to form the lowest estimate of the value of engineers. This is possibly owing to the fact that men forming such boards seldom have any knowledge of engineering, and, as the money for the works does not come out of their pockets, they fail to appreciate the false economy of employing incompetent men.

It is not long since the Commissioners for a somewhat important harbor and port required the services of an engineer, and issued a printed memorandum on the duties they expected him to perform. He was to carry out the construction of a concrete block breakwater, the build-

ing of a sea wall, and the designing and execution of such other works as were required from time to time; and to have charge of the repairs of a lighthouse, ferry, piers, &c., and the supervision of the men employed on all works. He ought to have a sound knowledge of the commercial value of materials and labor, as the works were to be carried out without the aid of contractors. The making of marine surveys, the taking of periodical soundings in the bay, and the dredging and dredge plant, were also to be placed in his hands. In addition to his professional duties he was to act as harbor master, accountant, and secretary to the Commissioners. They required a surety of £500, and, after reserving the right of separating the offices, named the enormous salary of £350 per annum for the combined appointments.

In this instance the Commissioners merely followed the doubtful lead set by many Bodies responsible for the carrying out of operations involving the expenditure of thousands, who do not trouble themselves to ascertain the market value of men capable of properly undertaking their work. It is, however, pleasing to be aware that, even in these dull times, a commodity of this nature commands three or even four times the figure set upon it by the Commissioners in question.

*Punch's* advice to those about to marry, "Don't," aptly applies to those purposing to enter the profession as a money-making business. This does not imply that a livelihood cannot be obtained by hard work in this as in other professions. Any one with ability, and a mind above mere money grubbing, may find work to suit his inclinations either in the office, field, study, works, or even in the wilds of unexplored countries. While in the rank and file of the profession he will be very poorly paid, considering the amount expended on his technical education and the social position he is expected to occupy. He cannot hope to leave the ranks until he is nearly thirty years of age. Even before that he may possibly secure a salary of £300 or £400 per annum, but on entering the profession and for no short period of his early life he can only calculate on earning a few guineas per week.

At the age of twenty-eight or thirty superior berths of various descriptions open to him; if he is possessed of mechanical talents he may obtain an appointment as manager of works, or become a partner in an established firm. Those who prefer to go abroad may take charge of surveying expeditions, and the carrying out of foreign work for contractors and others. Home-birds may content themselves with municipal engineering and offices under engineers-in-chief to Public Bodies

Although there are many public appointments in which the remuneration exceeds £1000, and a few in England even reaching £5000 per annum, the man who purposes working under others all his lifetime can, only in exceptional instances, expect to make more than £700 or £800 per annum during any portion of his career, and it is not probable that he will reach that figure before he has attained an advanced age. In America, Japan, India, and other foreign countries, matters follow much the same course; and although the salaries paid may be nominally larger, the purchasing value of money is reduced as the cost of the necessities of life are enhanced.

It is still satisfactory to know that, although the scale of remuneration is small, a young engineer, when thoroughly master of the details and routine of his profession, may at all times rely upon obtaining work of one kind or other. He is thus placed in a position of independence when compared with young men who enter the mercantile world, and if he be scrupulously careful he may be able to save a sufficient sum of money to defray incidental expenses by the time he is competent to undertake a private practice.

The difficulties facing a young man entering upon a private practice are great. The sums of money involved in engineering undertakings are so large that people are rarely disposed to entrust them to an untried man, although he may have gained some reputation, and rather prefer placing their works in the hands of established men. Then, again, young men are, as a rule, put down by a majority of persons as being entirely devoid of wisdom; consultation fees are not likely, therefore, to pour in at a very rapid rate. In the witness box the most

able evidence of a young engineer is weakened simply by the opposition counsel asking the witness his age. After an engineer has to some extent established himself, he will still have to encounter many difficulties not experienced by other professions. A barrister, doctor, or lawyer has only to conduct his early work well, and it forms the nucleus of a more extended practice. An engineer may conduct his work in the most able and skillful manner, but on its completion he receives the thanks of his friends, and says adieu to them and the work, and it will probably be some time before his clients require a similar undertaking carried out.

This by no means implies that he should have a contempt for other people's capital, or carry his work through in a careless or haphazard manner. His reputation as an engineer entirely depends upon his work, and his success in life on his reputation.

It requires the labor of years to make a reputation, and the man essaying to do it may often be in a very sorry plight. If he has integrity, ability, and perseverance he will find a few friends to assist him in the unpropitious times of his youth; and then it is to be remembered that a well-balanced mind can accommodate itself to the vicissitudes of fortune.

An engineer need never be ashamed of poverty, and should be actuated by higher motives than mere money getting. The love of his profession, if he possess it, will go far to sustain him through trying circumstances, and should occupy in his mind the position attributed to the love of knowledge by Sydney Smith when he said "I solemnly declare that but for the love of knowledge I should consider the life of the merest hedger and ditcher as preferable to that of the greatest and richest man here present; for the fire of our minds is like the fire which the Persians burn in the mountains: it flames night and day, and is immortal and not to be quenched—upon something it must act and feed—upon the pure spirit of knowledge, or upon the foul dregs of polluting passions."

The gigantic works executed by the ancients have already been referred to, and whilst admitting their magnitude they must by no means be considered as exhibiting superior skill to that existing

at the present day. In the works of the Suez Canal and Mont Cenis Tunnel, nature's barriers to national intercommunication have been removed by the skill of men now living. The blowing up of the mass of rocks in the "Hell Gate"; the deepening of the Mississippi mouths; the construction of the East River Bridge, New York; and, lastly, in our own country the Tay Bridge and the Metropolitan Railway, carrying annually its millions, and adding to the health and comfort of the inhabitants of one of the largest cities in the world, are all instances of the scientific progress of our profession, and will long remain as monuments to immortalize such names as Lesseps, Sommeiller, Grattoni, Eads, and Fowler.

Equally magnificent and useful works still remain to be accomplished. The great continents of North and South America have yet to be separated by a canal across the Isthmus of Panama. India has to be irrigated; the English Channel to be tunneled. China, Japan, South America, Africa, Persia, and Russia have yet to be opened up by the work of the engineer. These and other undertakings provide amply sufficient fields for the employment of our energies for an indefinite period; and if the abilities bestowed by a Supreme Being be directed to the accomplishment of such

objects, we may rest assured that, however little appreciated at the time, our lives have not been lived in vain.

In conclusion, gentlemen, as this is the last time I shall have the pleasure of addressing you from this chair—some of you being aware that I am about to face the difficulties already alluded to in my endeavors to establish a private practice in Westminster—permit me to avail myself of this opportunity to thank you most sincerely for having placed me in the position which I this evening vacate, for the kind assistance and co-operation you have at all times afforded me in my endeavors to advance the interests of this society, and for rendering my term of office such that its remembrance cannot but prove for me a lasting and pleasant retrospect. I may say I look forward with no small degree of confidence to the time when this shall become one of the standard institutions of the West of England. And now, in taking leave of you, allow me to express the hope that each member will do all that in him lies to achieve this result, by which he will not only do honor to his profession and advance the cause of civilization, but will also promote his own individual interests, ever bearing in mind "There is a tide in the affairs of men, which, taken at the flood, leads on to fortune." (Applause.)

## THE "GEOMETRY OF POSITION" APPLIED TO SURVEYING.

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Written for VAN NOSTRAND'S MAGAZINE.

### II.

THE proposition of the Geometry of Position relative to the four points at the intersection of two pairs of concurrent lines, (Fig. 3) is readily applicable to the solution of a second class of problems of very common occurrence in surveying,—the measurement of inaccessible distances.

The cases which, in practice, fall under this head are almost innumerable; as the measurement of the width of a river, the distance across a marsh, the distance of a lighthouse or a beacon from the shore,

&c. Yet the solution of any one of them by the Geometry of Position is ample enough to cover them all. To take the first example above cited, let it be required to find the distance of a point C (Fig. 7), on one bank of a river, from a point D, on the opposite bank.

To accomplish this, set the instrument at the point C, sight to D, plunge the telescope, and take any point in the line of sight as A. The line CA will then evidently be a continuation of the line CD, the distance to be measured. Now,

take *any* point *off* the line CA as *a*, such that both C and D are visible from it, set the instrument at this point, sight to D, and take *any* point in the line of sight *aD* as *c*. Then sight to A, previously chosen anywhere on CA, and "stake out" that part of the line *aA*, which seems to cross a line joining *cC*. Sight next to C (the instrument being still at *a*) and "stake out" that portion of the line *aC* which seems to cross a line joining *c* and A. Move now to *c*, sight to C, and locate *b*; then sight to A and locate *d*. Set the instrument at *d*, sight to *b*, and find B where the line of sight cuts the line CA. Finally, measuring the distances CB and BA and substituting in equation A,

$$CD = \frac{BC \times AC}{AB - BC},$$

the distance across the river is found. Thus if  $BC=48.99$  feet, then  $BA=51.01$  feet, and

$$CD = \frac{48.99' \times 100'}{2.02'} = 2,425.24 \text{ feet.}$$

It is not, however, to be supposed that this proposition of the Geometry of Position does not equally apply to cases in which it is desirable to find the distance and direction of two or more objects from some fixed point. To take an example, suppose at A and C, in Figure 8, are two objects whose distances and directions from some fixed point *b* it is desirable to know.

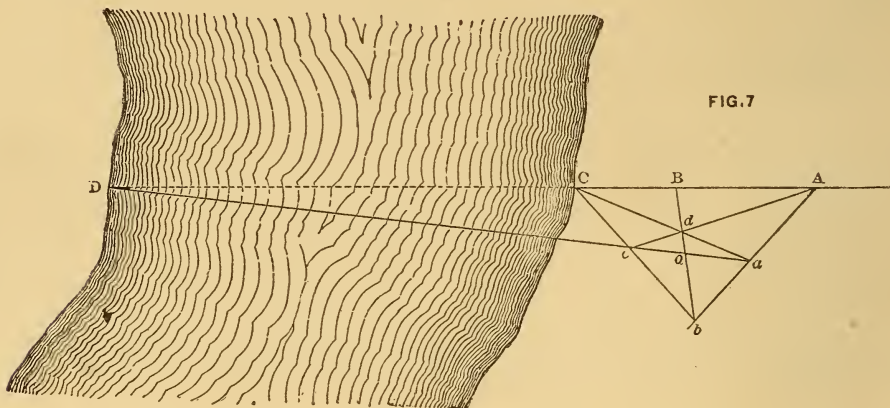


FIG. 7

Referring to Fig. 7, it is evident that if  $a, A, d, o$  be considered as the four points of intersection of two pairs of diverging rays from *c* and *b*, and  $bc$  the line joining the points of divergence (*b* and *c*) of the two pairs of rays, then will the diagonals  $ad$  and  $oA$  (Fig. 8) of the figure  $aAod$ , intersect the line  $bc$  in the two points *e* and *e* respectively. The four points *b, e, c, C*, will then form an anharmonic range, and from the principles of anharmonic section, already explained, it results that

$$cC = \frac{ce \times cb}{eb - ce}$$

Again, regarding the points *b* and *a* as the points of divergence of the pairs of rays intersecting each other in the four points  $Ccod$ , and the line  $ba$  as the connector of the points of divergence *b* and *a*, the two diagonals  $cd$  and  $Co$ , of the figure  $Ccod$  will intersect the connector

$ab$  in the two points A and *g* (Fig. 8) respectively. Those two points will form with *a* and *b* an anharmonic range from which may be obtained,

$$aA = \frac{ga \times ab}{bg - ga}.$$

But  $bC = bc + cC$  and  $bA = ba + aA$ , from which the distance required may be readily obtained.

To apply this to the case just taken. The point *b* having been selected, the solution of the question depends on finding the distances  $bC$  and  $bA$  and the bearings of these lines. To obtain these, set the instrument at *any* point between *b* and the objects, as *o*, and sighting in *any* direction such that the line of sight does not cut the line CA, anywhere between C and A, locate a few points on the line of sight about where it seems to cut a line joining *b* and C. Plunge the telescope, and in a similar way locate a

few points about where the line of sight seems to cut a line joining  $b$  and  $A$ . Sight next to  $C$  and locate  $g$  as nearly as possible; and then sight to  $A$  and locate  $e$  approximately by setting a few stakes where the line of sight  $Ao$  seems to cut  $bC$ . This done move the instrument to  $b$ , sight to  $C$  and locate  $e$  and  $c$  with great exactness. Sight next to  $A$  and

locate  $g$  and  $a$ . Now, having measured  $be$  and  $ec$ , as also  $bg$  and  $ga$ , and substituting these values in the two equations above given, the values of  $cC$  and  $aA$ , are found, which, added to  $bc$  and  $ba$  give the required distances  $bC$  and  $bA$ . The magnetic bearings are, of course, taken when the instrument is at  $b$ .

Without stopping to name over the

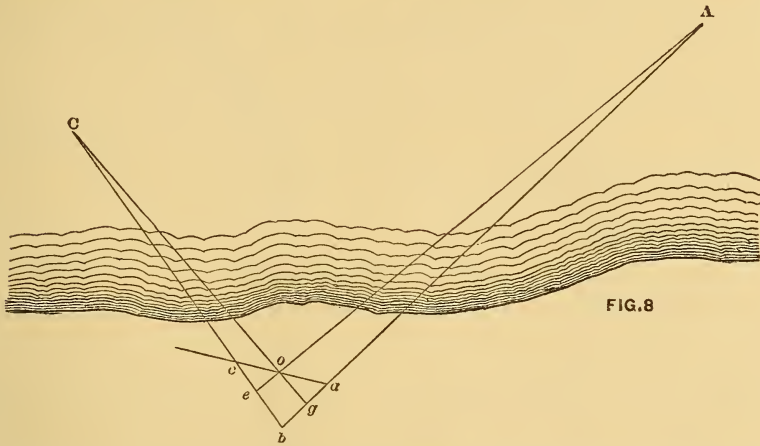


FIG. 8

many instances in which it will be advantageous to apply the two methods of measuring distances illustrated in Figs. 7 and 8, I shall pass to the consideration of a more important matter, the degree of accuracy of the two methods.

Beginning with the first mentioned method (that illustrated in Fig. 7), it is needless to observe that the point  $A$  on the line  $cD$  may be taken at any distance from  $C$ . To simplify the measurement, therefore, the distance  $AC$  may be taken at one hundred feet and laid off at once by means of a tape. But the distances  $AB$  and  $BC$  must be measured with great care and to the smallest fraction of a foot. For it is evident from equation A, that as the value of  $BC$  approaches that of  $AB$ , the value of  $CD$  in the expression

$$cD = \frac{Bc \times Ae}{AB - Bc}$$

approach infinity, because when  $AB = Bc$  the value of  $cD$  is infinity. It follows therefore that when the distance to be measured is quite a long one, the difference between  $AB$  and  $BC$  will be very small, indeed but a decimal of a foot. To illustrate with an extreme case, suppose the distance to be measured is 499,950

feet, or something over 94.7 miles; then

$$cD = \frac{49.955' \times 100'}{50.005 - 49.995} = 499950 \text{ feet.}$$

A difference then of .01 of a foot between  $AB$  and  $BC$  will correspond to a distance  $CD = 94.74$  miles. To take a more likely case, suppose  $AB = 50.1'$  and  $BC = 49.9'$  feet, the distance  $AC$  being one hundred feet; then

$$CD = \frac{49.9' \times 100'}{50.1' - 49.9'} = 24950 \text{ feet,}$$

a distance equal to 4.725 miles. In proportion as the distances to be measured are shorter, the differences between  $AB$  and  $BC$  are larger. Thus, a distance of 2425.24 feet corresponds to a difference between  $AB$  and  $BC$  of 2.02 feet, while a distance of 1199.37 feet will correspond to a difference between  $AB$  and  $BC$  of 4.002 feet. A distance of 1 foot on  $CD$  will therefore have an exceedingly small difference. If the distance  $CD$ , be very great, as five thousand or six thousand feet, the difference between  $AB$  and  $BC$  corresponding to a foot on  $CD$  will be at least some ten thousandths of a foot; if the distance  $CD$  be, on the other hand, from one to two thousand feet,

the difference between AB and BC corresponding to a foot on CD will be about one thousandth of a foot. To obtain accurate results it thus becomes quite necessary to be able to measure the distance BC to the ten thousandth of a foot for very large distances, and to the thousandth of a foot for all small or ordinary distances. Thus a distance of 1199.37 feet corresponds to a difference between AB and BC of 4.002 feet, but an increase in the difference to 4.004 of a foot will correspond to a value for CD of 1198.76 feet. Here therefore a distance of .61 of a foot is measured by a difference of .002 of a foot.

This fineness and accuracy of measurement constitutes perhaps, the main objection to the methods discussed above. Yet it is one not impossible to overcome. The distance AC is, for instance, one hundred feet, measured off with all possible accuracy, the temperature and horizontal position of the tape being, of course, fully considered. Now the point B can never fall anywhere on AC except between the middle point of AC and C. For if it falls *exactly* midway between A and C, the point D is at an infinite distance from C or CD is infinitely great. Neither can B fall between A and the middle point of AC, as in that case the point D would fall on the opposite side of A, or, in other words, the point A would be *between* D and B. This never *can* happen in either of the two methods given above, because A and C are chosen at pleasure, and the point D being *sighted to first*, its anharmonic conjugate B must invariably fall between A and C. As a consequence of this fact, it follows that the measurements to the hundredths and thousandths of a foot, need not begin until the fiftieth foot has been passed. Nor, on the other hand, is it necessary that the measurement shall extend for any great distance. If AB be equal to 50.003 and BC 49.997 feet, the value of CD will be over one hundred and fifty-seven miles; if, on the other hand, AB be 55 feet, and BC 45; the difference will be ten feet, and CD will be 450 feet. It will never be necessary, therefore, to go so near the fifty foot point as .01 of a foot, nor so far away as ten feet. The fine measurements, in other words, will be confined to ten feet, and may be obtained in a

number of ways that readily suggest themselves. The simplest is by means of a well constructed leveling rod, with a sliding target. If this be used, the center point of the distance AC should first be carefully found, and one end of the rod placed exactly over the point by means of a plum bob, and the rod put horizontally in line with the instrument. It is best to have some simple support for the rod to keep it off the ground, and to enable it to be placed truly horizontal by the aid of a bubble. This done, and the sight *bd*, (Fig. 7), taken to determine the point B, the target may be moved along till it crosses the line of sight, and the distance AB obtained to the thousandth of a foot. If the distance to be measured is very large the vernier must read to ten thousandths of a foot, or the results obtained will be utterly worthless.

The extreme accuracy and fineness of the measurement, thus necessary when long distances are to be measured, render it doubtful, to say the least, whether the methods in question are superior or more practicable than those now in use. The accuracy, however, to be exercised in the measurement of the one hundred feet required between C and A, Fig. 7, is no greater than should be exercised in the measurement of ordinary lines in city surveying, while distances commonly met with in surveying, as the width of a river, or stream, the distance over a marsh, etc., can be obtained without measuring finer than the one thousandth of a foot, which may be done with a common leveling rod. For example, if the distance AB=51.16 feet, and AC=100' then the distance BC=48.24 feet and Eq. A.

$$CD = \frac{48.24' \times 100'}{3.52'} = 1370.45.$$

But if AB=51.761 feet then BC=48,239 feet and

$$CD = \frac{48.239' \times 100'}{3.522'} = 1369.647$$

a difference of about eight-tenths of foot. The question then, as to whether this method is better than the old method by logarithms, resolves itself into this; is it better to make one short accurate measurement on the ground, or to make large linear and angular measurements

on the ground, and solve by the rules of trigonometry?

For the solution of such problems in surveying as do not require the measurement of distances, the Geometry of Position affords methods, the merits of which are unquestionable. Such prob-

lems are those requiring the location of lines and very likely to occur in laying out and dividing land, as also in chain surveying, and in town surveying. To take an instance, having two converging lines given as AB and CD Fig. 9, let it be required to pass a line through their

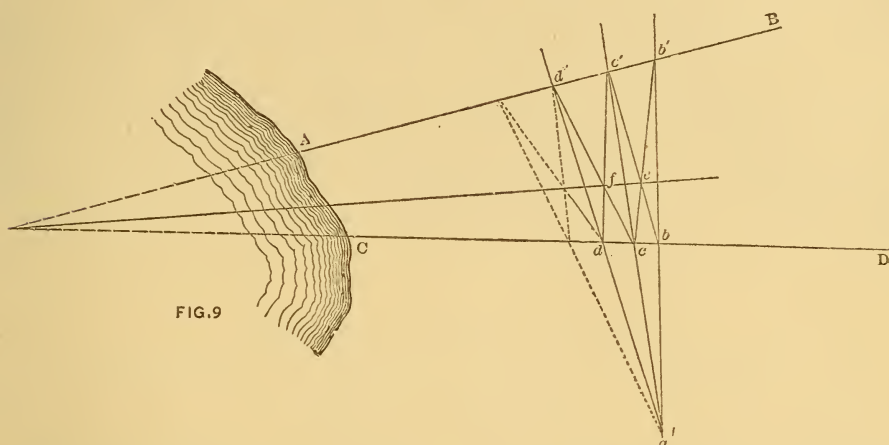


FIG. 9

invisible point of intersection. If it be merely required that the line shall pass through the point of intersection, the problem is of the most general form and may be solved as follows: Set the instrument at *any* point not within the lines as *a*, and sighting across them both locate the points *b* and *b'* where the line of sight cuts them. Then turn the

telescope so as to cut them at any other place and locate the points *c* and *c'*. Turn the telescope through another angle and locate the points *d* and *d'* as before. Move then to *b* and sighting to *c'* locate the middle part of the diagonal *bc'*. Then move to *c*, sight to *b'* and find *e* exactly, and continue this operation till the diagonals *cd'* and *dc'* are located

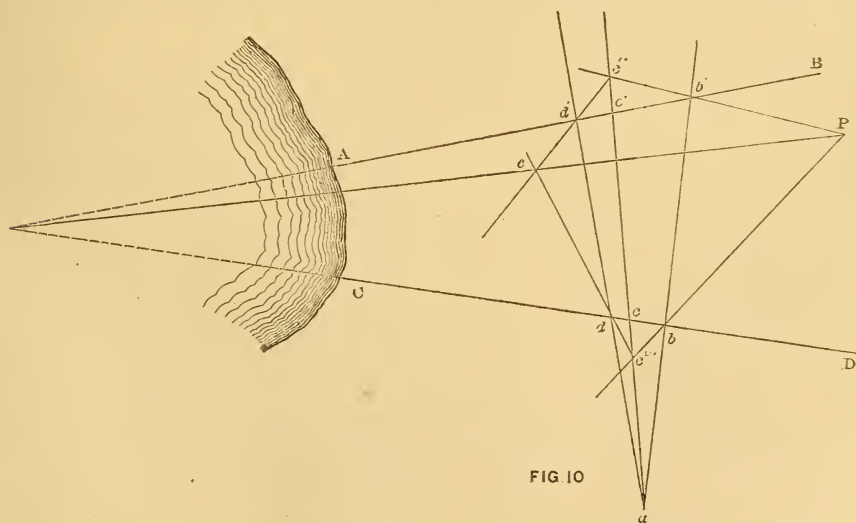


FIG 10

and *f* found. The line joining *ef* passes through the point of intersection of AB and CD. Although two points are

enough to determine the line *ef* an additional point may be obtained as shown by the dotted lines in the figure. In

using this method it does not make any difference where  $a$  is taken without the line, nor is any account taken of the angles the lines  $ab$ ,  $ac$ ,  $ad$ , etc., make with each other.

If the problem takes a more limited form, and the line must pass through a *given point* and the intersection of AB and BC, the solution may be affected in this wise. Let P (Fig. 10), be the given point. Set the instrument, as in the last case, at any point off the two lines as  $a$  and locate, as before, the points  $b$  and  $b'$ ;  $c$  and  $c'$ ;  $d$  and  $d'$ . Now move to the point P through which the line is to pass, and sighting to  $b'$  locate  $c''$  where the line of sight cuts  $ac$ . Also sight to  $b$  and determine  $c'''$ . Move to  $c''$  sight to  $d'$  and

stake out a portion of the line  $c''d'$  beyond  $d'$ . Finally, move to  $c'''$ , sight to  $d$  and find  $e$  exactly. The line through P will pass through the intersection of AB and CD. If the lines AB and CD are very far apart, some time and trouble may be saved by beginning at  $b$ , sighting to P and find  $c'''$ . Then setting the instrument at  $c'''$  sighting to  $d$  and locating a part of the line  $c'''d$ . Repeating this on the other side, beginning with  $b'$  the point  $e$  is readily found.

When the point P, instead of being *within* the angle made by AB and BC as to the case in Fig. 10, lies *without* the angle as shown in Fig. 11, the line may still be found as in the previous case.

Where it is possible to put the instru-

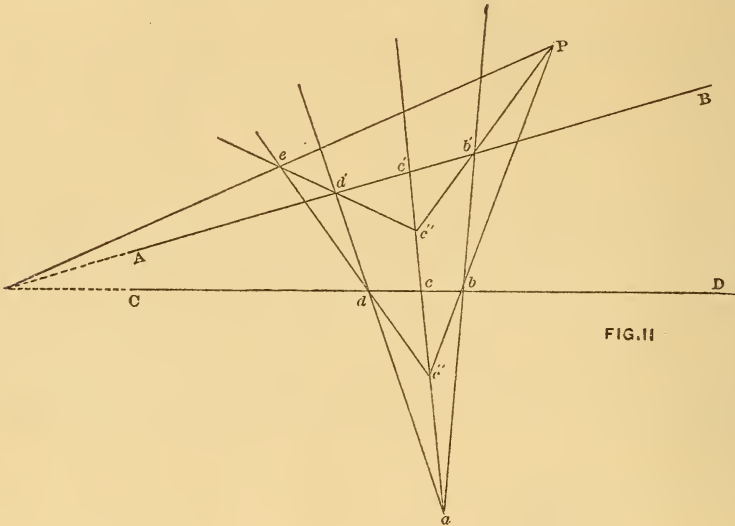


FIG. 11

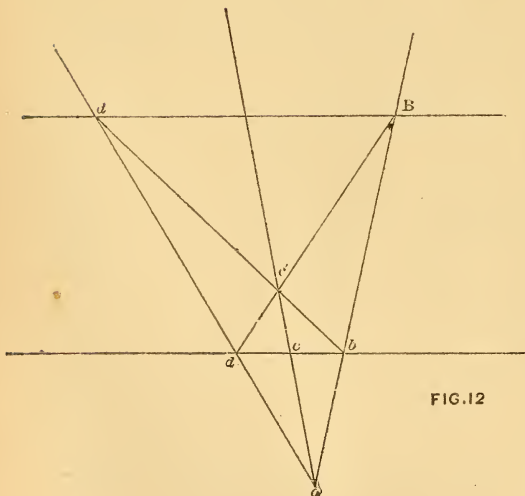


FIG. 12

ment (when used) exactly on the line, a simple method is to begin at  $b$  (Fig. 11), sight in any direction and determine  $b'$  and then  $a$  anywhere on  $bb'$  produced. Then sight to P and find  $c'''$  approximately. Next take any other point as  $c$  sight to  $a$  and find  $c'''$  exactly, and  $c''$  approximately. Then take  $d$  anywhere on the line CD, sight to  $a$  and find  $d'$ , then to  $c'''$  and find  $e$  as nearly as may be, then find  $c''$  by moving to  $b'$  and finally  $e'$  by moving to  $c''$  and sighting to  $d'$ .

Of the two, the first method is perhaps of more general application, as it affords simple methods of bisecting, trisecting, &c., the angle formed by the two lines, as will be shown when considering the application of the Geometry of Position to drawing. It likewise affords a solu-

tion to the problem,—of passing a line through a given point parallel to a given line. Let  $AB$  figure 12 be the given line and  $P$  the point through which it is required to pass a line parallel to  $AB$ . Referring to figure 9, it will readily be seen, that, if  $C'$  and  $d'$  be regarded as the points of divergence of two pairs of rays intersecting at  $fdac$ , then will  $dc$  be one diagonal and  $af$  the other. But if this latter,  $af$ , be made to cut  $d'c'$  just midway, then will  $cd$  be parallel to  $AB$ . This gives the solution for the problem in question. Lay off on the given line anywhere, two equal distances  $bc$  and  $cd$ . Through the point  $b$  and the given point

$P$  draw a line and in it take *any* point as  $a$ . From  $a$  draw lines of indefinite length through  $c$  and  $d$ ; join  $dP$  and mark the point  $c'$  in which it cuts the line  $ac$ . Through  $b$  and  $c'$  draw a line till it cuts  $ad$  at  $d'$ . Then is  $d'$  a point on a line through  $P$  parallel to  $AB$ .

The solution is undoubtedly of most use in chain surveying; yet it is evident that as affording a means of obtaining the bearing of an inaccessible line, of which two points only are to be seen, it is of value in all branches of surveying. By obtaining a line *parallel* to the inaccessible line, and then finding its bearing the desired result is accomplished.

## SIZES OF SAFETY VALVES.

By PROF. R. H. THURSTON, of the Stevens Institute of Technology.

From "American Machinist."

THE office of a safety valve, as used on a steam boiler, is to discharge steam so rapidly, when the pressure within the boiler reaches a fixed limit, that no important increase of pressure can then occur, however rapidly steam may be made. It has also another office: it should be so constructed and arranged that, should any accident occur, it may be opened by hand and the steam pressure lowered very rapidly, even when the fires in the boiler are burning brightly and generating steam with maximum rapidity. The size of a safety valve is determined by the character of the valve itself, by the pressure at which the steam is to be discharged, by the difference permissible between the pressure at which the valve is to open automatically, and that at which it is intended to be capable of discharging steam as fast as the boiler can make it.

A valve of defective design or badly constructed must necessarily be larger, to do the same work, than one of similar type well designed and constructed. Steam is discharged at any given rate through an orifice of smaller dimensions as the pressure increases: the lower the pressure, on the other hand, the larger must be the valve. A boiler in which steam is carried at twenty pounds by gauge may require a safety valve of

thirty inches area, while the same quantity of steam would escape through a rivet hole in a boiler containing steam at pressures such as were attained by Perkins and Albans a generation ago.

Rules by which to calculate the proper area of safety valves for every case arising in his practice, are used by every engineer accustomed to designing steam boilers. These rules vary considerably with differences in the experience or the judgment of their authors. The builder is often inclined to adopt valves of too small size because of the expense of putting on large valves. The engineer, who has once nearly met with a serious accident, to obtain ample security against a repetition of the experience, at once adopts valves of excessive areas; and the designing engineer sometimes bases his rule on improper assumptions, or is ignorant of the true conditions or of the proper method of stating them in the form of a rule. Attention has lately been called to these discrepancies between the rules given by various so-called authorities by a writer in a well-known periodical; but that writer, unfortunately, concludes by commending the rule of Prof. Rankine, which, for general applications, is about the most defective of all. It is correct for certain pressures and under the conditions which existed

in the experiments and observations on which it is based. Containing no reference to the pressure of steam, however, it simply misleads when generally applied. The conclusion is, not that Rankine was careless in framing the rule, but that the engineer, in applying it, must understand under what circumstances it is applicable. The same remarks apply in some degree to rules attributed to the writer. The discrepancies noted in the report of the U. S. Committee on Safety Valves would have been less marked had the rules been properly used.

A rule for general application must always give an area determined by the quantity of steam to be discharged, and the pressure at which it is to be discharged. A perfectly exact rule would involve the determination of other quantities, as the specific volume of the steam, the proportion of water carried by it in suspension, the difference between internal and external pressure. For the purposes of the engineers, these quantities may be neglected, or may be taken into account by a simple modification of the formula used, as will be presently shown.

Rules are very commonly proposed which are based upon the amount of coal burned per hour in the given case. Such rules involve the assumption that each pound of coal evaporates a definite and known quantity of water. Another class of rules make the area of the valve depend upon the dimensions of the boiler, as on the area of heating or of grate surface. These rules involve an assumption that the area of heating or of grate surface is proportional to the quantity of steam made in the boiler in a given time. It is evident that, with a given boiler, the conditions upon which rules of the first class are based are variable, while those of the second are constant. Rules based upon the weight of steam made, or of coal burned, in the boiler must therefore be determined by the *maximum* consumption of coal or production of steam for which the boiler is proportioned. Rules based upon the size of the boiler or area of its grate surface must be so constructed, that the area given by them will be ample for the discharge of more steam than the boiler can make by evaporation from the given amount of heating surface, or by the

combustion of all the coal that can be burned upon the grate under the conditions of draught which are to be anticipated. Properly constructed and properly used, it is a matter of perfect indifference which kind of rule is adopted. The two classes of rules will give the same results if both are intelligently framed and applied.

The weight of steam in pounds which will escape through an orifice in the boiler having an area of one square inch is, in ordinary practice, very nearly fifteen times the pressure of the steam measured from the absolute zero of pressure, *i.e.*, above a vacuum. The area of opening, therefore, for any boiler must be, in square inches, the weight of water evaporated per hour as a maximum, divided by fifty times the gauge pressure with fifteen pounds added; *i.e.*

$$A = \frac{w}{50, (p + 15)},$$

or,  $a = 0.02 [w \div (p + 15)].$

But a safety valve, as has been stated, should be capable of discharging very much more than the maximum quantity of steam that the boiler can make when doing its best. The valve must be raised, ordinarily, by the action of the steam itself, and the force exerted by the steam pressure upon its disk rapidly diminishes as it rises from its seat. The seat is beveled, too, in such a manner that the effective area for discharge of steam is but a fraction of that due the rise of a valve having an unbeveled seat. It is therefore advisable to give a large excess of area over that above determined. How great this excess shall be is very generally determined by the judgment of the engineer, as formed by observation and experience and checked by direct experiment. Very few engineers, probably, err seriously on the side of excess.

In making up a set of rules for safety valve areas some years ago, the writer adopted the rule: multiply the maximum weight of steam which the boiler is expected to generate per hour by five and divide by ten times the gauge pressure increased by ten; or, divide that weight by twice the latter quantity. Thus,

$$a = \frac{0.5 w}{p + 10}.$$

From this rule, it is easy to deduce special rules for any other desired application; as to boilers of which the dimensions are given. Thus, the writer had occasion to design safety valves for steam boilers having a ratio of grate to heating surface of about one to twenty-five. These boilers had a "natural draught" and were expected to burn, as a maximum about fifteen pounds of coal per square foot of grate. Such boilers will make, as a maximum, about five pounds of steam per hour per square foot of heating surface. A simple calculation based on these data would give the following set of formulas, in which  $w$ =the maximum weight of steam made per hour,  $h$ =the area of heating surface,  $g$ =that of the grate surface, and  $c$ =the maximum amount of coal burned per hour.

$$A = \frac{0.5 w}{p+10} \quad \dots (1)$$

$$= \frac{2.5 h}{p+10} \quad \dots (2)$$

$$= \frac{62.5 g}{p+10} \quad \dots (3)$$

$$= \frac{4 c}{p+10} \quad \dots (4).$$

For boilers having different proportions, as locomotive boilers with their tremendous forced draughts, or some stationary and marine boilers with their vastly greater proportion of heating to grate surface or to steam made per hour; special rules must be constructed if the designer wishes to base his calculations upon their dimensions. As has been shown above, it is very easy to make such rules, the first of the set having been determined upon. No intelligent engineer will attempt to apply rules like Nos. 2, 3, or 4 to exceptional cases, or, indeed, to use them at all without knowing upon what authority and upon what kind of practice they are based.

Rules in which the steam pressure is not taken into account are only applicable to some one pressure. The same caution is to be observed in using them. It is further evident that rules and formulas are not to be compared except where they are adapted to the same set of conditions, as in the example just given.

Very large boilers require such great area of opening for their safety valves that it is necessary to divide it between two valves; in fact it is always much better to have two valves, even on small boilers. If an accident happens to one, the other is then to be relied upon, usually, to discharge the steam.

The forms of safety valves are almost numberless. A description of some of the best is to be found in the report of the committee on tests of safety valves, appointed from the U. S. Board of Supervising Inspectors of Steam Vessels, in 1875. Among the very best is the ordinary "Lever Safety Valve," of Papin, as modified by the introduction of knife-edged bearing pins by that committee. An excellent little treatise on the safety valve was published in the *R. R. Gazette*, in 1875, by Mr. R. H. Buel and reprinted in Van Nostrand's "Science Series," No. 21. It gives a tolerably complete summary of the principles involved in the design and construction of this most important of the attachments to the steam boiler.

## REPORTS OF ENGINEERING SOCIETIES.

**A**MERICAN SOCIETY OF CIVIL ENGINEERS.—The papers by the Society, not heretofore noticed, are:

Relative Quantities of Material in Bridges of Different Kinds and Various Heights, by Chas. E. Emery.

Description of Survey for Determining the Slope of Water Surface in Erie Canal, by W. H. Searles.

## IRON AND STEEL NOTES.

**T**HE total amount of iron ore produced in 1876 in the United Kingdom was 16,341,583 tons, and the value £6,825,705. The pig iron produced from the ore was 6,555,997 tons, and the value of the raw material was increased by the expenditure of coal and labor in smelting to £16,062,192. These figures show a considerable increase over the production in 1875. In that year 15,821,060 tons of iron ore, valued at £5,975,410, were raised, and 6,365,462 tons of pig iron, valued at £15,645,774, produced. The increase has been chiefly in the Cleveland district and in Scotland. The production of Scotch pig iron has increased from 807,677 tons in 1874 to 1,103,000 tons in 1876. The Scotch ore requires a relatively large quantity of coal, and the low price of coal has assisted production. The total amount of coal used in the making of pig iron in 1876 was 15,598,381 tons. Much of this was, in fact, used in the form of coke. The Royal Commission on Coal reckoned that three tons of coal are used on

the average to make one ton of pig iron. The figures quoted show that pig iron is now more economically made. It appears from them that the quantity of coal used per ton of pig iron is considerably less on the average than 2½ tons. In addition to the iron ore raised in the United Kingdom, we smelted in 1876 672,235 tons of imported ore, and derived 300,000 tons of burnt or purple ore from imported cupreous pyrites which raised the total quantity smelted to 17,813,818 tons. The current issue of the statistics omits many tables found in the previous publications. Among added lists is one of firms using the Siemens and Siemens-Martin processes for steel. It is printed opposite the list of those using the Bessemer converters, and some names, as that of the London and North-Western Railway Company and the Dowlais Iron Company, appear in both categories.

THE *Berlin Borsen Zeitung* publishes the following table of prices for Bessemer and iron rails respectively at the times stated during the past four years:

	Bessemer rails.	Iron rails.
	Marks per kilog.	Marks per kilog.
1873. Beginning of the year..	41.67	35.80
Middle of the year. . .	39.31	33.63
End of the year. . . . .	35.42	27.12
1874. Beginning of the year..	35.60	28.76
Middle of the year. . . .	29.85	19.37
End of the year. . . . .	26.31	18.32
1875. Beginning of the year..	26.14	18.93
Middle of the year. . . .	21.30	17.41
End of the year. . . . .	19.53	17.50
1876. Beginning of the year..	18.87	15.31
Middle of the year. . . .	16.93	15.00
End of the year. . . . .	17.75	16.93

#### RAILWAY NOTES.

THE working of the Mediterranean or Western group of lines which has just been formed by the Italian Government is to be entrusted to the Italian *Credit Mobilier* and the General Bank of Rome.

A COMPANY is, says *Le Propagateur*, being formed in Paris with a capital of 200,000 francs, which will be employed in defraying the cost of designing and constructing a steam tramway motor, and in experiments, in order to discover the most economic method of working street tramways by steam power.

BERLIN is at a loss as to the disposal of its Metropolitan Railway. Soon after the Franco-Prussia war Berlin found it necessary to have a railway. It has now 1,000,000 inhabitants, who live in flats four stories high without gardens, parks, and with but a few squares, so that it is, in comparison to London, of but small extent, and a railway is not actually needed even now, much less five years ago. However Berlin had made up its mind to have a railway of its own, and a capital of 78,000,000 marks was soon subscribed. The State took 21,000,000 marks, the German Building Co., 12,000,000 marks, and three railway companies took the rest.

A RECENT number of the *Annales des Ponts et Chaussées* gives the following information,

furnished by the officers of the railway from Hanover and Cologne to Minden. The proportion of pine ties, injected with zinc, renewed after twenty-one years, was 21 per cent; beech ties, injected with creosote, renewed after twenty-two years, 46 per cent; oak ties, not injected after seventeen years, 49 per cent; oak ties injected with chloride of zinc, after seventeen years, 20.7 per cent. The ties which were not renewed appeared perfectly sound. Since 1870, the Emperor-Ferdinand Northern Railway has used only oak ties, injected with either creosote or with chloride of lime.

MESSRS. FOX, WALKER, & Co., of Bristol, have been entrusted by Mr. Vignoles, the engineer for the Rouen tramways, with the design and execution of six locomotives for working the traffic, and the first of these engines has, during the last week, been subjected to a series of severe trials on what is probably the most difficult tramway system in the world, that of the city of Bristol. Besides various steep gradients for long distances, and the sharp curves on turning from one narrow street to another at right angles, there is in Maudlin street an incline of 1 in 12 for a distance of 90 yards, including a curve of 45 feet radius at the summit. Yet this combination of difficulties was, on Saturday last surmounted by the locomotive, in the presence of the engineer and directors of the Bristol Tramways Company. The engine is 10 feet 6 inches long over all, the wheel-base being 4 feet 6 inches, and the gauge rather less than 4 feet 8½ inches. The ends are rounded, so as to clear in running round curves, and the connections are made by a combined coupling and central buffer. A cab encloses the engine, giving it the appearance of an ordinary tram-car, while wrought iron curtains, reaching down to within a few inches of the rails, completely conceal the wheels and side rods. Two flap doors at the side are, however, provided for oiling. The grate area is 4.6 square feet, and the total heating surface 96 square feet, providing ample steam for the pair of outside cylinders, 8 inches in diameter by 9 inch stroke the ports of which are rather large, so as to take steam easily, and get as much effective pressure on the piston as possible. The wheels are of cast steel, 2 feet in diameter, and all four coupled. The exhaust steam is caused to expand as much as possible by being passed through a cage made of wire wound spirally round an open cylindrical frame, and also through an annular orifice which causes it to completely fill the chimney instead of allowing it to issue in a central jet, by which means the usual noise of the blast is prevented. Smoke is avoided by the use of South Wales smokeless coal. The steam blowing off from the safety-valves is received in a casing, and led by a pipe into the ashpans, so as to damp down the fire, and thus acts as an automatic pressure regulator. The steam and water from the cylinder cocks, gauge cocks, and water gauge is led away into the ashpans, which is made double, so as to retain the ashes for the whole of the run; and the coal is charged on the bars in brown paper parcels for convenience, and also for the avoidance of dirt and dust. The steam

stop-valve is only used on starting and at the end of a journey, as the reversing lever, which can be shifted under steam, suffices for starting, stopping, and reversing on the run. By this means alone the engine can be stopped in its own length while running at the rate of ten miles an hour: but for descending sharp gradients, powerful break straps are applied by treadles to two cast iron pulleys keyed on the leading axle. The motion of the locomotive is remarkably easy, and no less so is the readiness with which she answers the regulator.

## ENGINEERING STRUCTURES.

**ST. GOTHARD TUNNEL.**—At the northern opening granitic beds have been encountered, and at the southern end abundant springs of water. These difficulties have been completely surmounted. The Italian journals anticipate the completion of the work by the spring of 1880, provided the necessary funds are raised. —*Les Mondes*.

**SHIP CANAL ON THE SEINE.**—Preliminary formalities are being carried through at Havre for the construction of a maritime canal from that port, touching at Harfleur, and joining the Seine at Tancarville, a point on the River about sixty miles below Rouen. By means of this canal the dangers of the navigation of the Lower Seine from fogs, the shifting sands, and the violence of the tidal wave, will be avoided. The canal will consist of a single section of about seventeen miles in length, the western outlet of which will be in the Eure Dock, at Havre. According to the plans adapted, the canal would have a minimum breadth of twenty-five meters (over eighty feet,) with a towing path six meters wide on each bank. Plans have been adopted for increasing the depth of the channel of the Seine between Paris and Rouen to three meters twenty (10½ feet); a minimum of three meters fifty has, consequently, been fixed for the canal; and as between Havre and Harfleur it is to be accessible for brigs, schooners, and steam colliers, the depth in that portion will be increased to 4½ meters. The cost of the work is estimated at 21,000,000 francs, including all accessory works, the planting of the banks with trees, the construction of a branch, 500 meters long, to connect the port of Harfleur with the canal, and a basin of 500 meters by 60 meters at Havre. —*Coal Journal*.

**DARIEN INTER-OCEANIC CANAL.**—At a recent meeting of the Academy of Sciences, in Paris, M. de Lesseps, the constructor of the Suez Canal, and President of a commission to consider the best means of accomplishing inter-oceanic communication across Central America, reported that after considerable preliminary examinations the Isthmus of Darien was the best route. It would have the immense advantage of not requiring any locks, as the Pacific and Atlantic are at a level in that region. The canal would have a total length of sixty-five kilometers (five-eighths of a mile each) from the point where the River Tuyra, which falls into the Pacific ceases to be navi-

gable to the Atlantic. The ground is very favorable, the vegetable mould varying in depth from two to seven meters, and below that soil is found, throughout nearly the whole length, tenacious clays, which are invaluable in a country subject to tropical rains, as they will not be washed away to silt up the canal. The whole district is covered with a virgin forest, containing trees admirably adapted for hydraulic purposes, as they are extremely hard, and are not attacked with worms. Limestone is found in ample quantities for the necessities of the undertaking. But—and here comes the difficulty—a tunnel will have to be made fourteen kilometers in length, and as a passage for the largest vessels will have to be provided, it must be thirty-six meters (118 feet) in height. Its construction is estimated to cost 300,000,000 francs, and the other works an equal sum. —*Railway Review*.

**AMERICAN BRIDGES FOR CANADA.**—The Phoenixville Bridge Company are building a number of iron bridges in the line of the Montreal, Ottawa, and Occidental Railway, Canada, under contract with the Canadian Government. Annexed are some details of these bridges. On the Eastern division there is one at St. Ann's, 40 miles west of Quebec, having seven spans of 160 feet each; one at Batiscan, with four fixed spans of 160 feet each, and a draw of the same length; and one at the Three Rivers, half way from Quebec to Montreal, of five spans, each 219 feet in length; and 50 feet from the water. On the Western division, at Buck River, 7 miles west of Montreal, a 50 foot span has been finished over a small stream, and near by two spans of 155 feet each, and one of 200 feet will soon be in place. At St. Rose one of five spans, of 155 feet each, is being built; at the Scholastic River, a 50 foot span; at La Chute three spans of 104 feet each; at Calumeta 50 feet span; at the River Rouge three deck spans of 150 feet each; at Ancheene Creek and Salmon Creek one deck span each of 50 feet; at Salmon River a 100 foot span; at North Nation River three spans of 100 feet, 150 and 200 feet; at Little Blanche River a 50 foot span, at River Blanche one span of 100 feet; across Au Leivereres River, at Buckingham, one span of 100 feet and three of 150 feet each; at Little Upper Blanche a deck bridge of 50 feet; at Upper Blanche, one span of 100 feet and at Gatineau four spans of 204 feet each. All these bridges are of wrought iron, with iron floor beams and track stringers, wooden ties 8 inches by 8 inches, and 8 inches apart, and the necessary guard rails and iron. They are shipped to Canada in barges by canal, and have to pay a duty of 17½ per cent. on their cost.

## ORDNANCE AND NAVAL.

**THE INFLEXIBLE.**—The report of the Committee composed of Admiral Sir James Hope, Dr. Woolley, Mr. G. W. Rendel, and Mr. Froude, appointed by the Admiralty to inquire into the stability of the Inflexible, has just been issued, and will be studied with the closest attention by all who are interested in our Royal Navy, and especially by naval archi-

fects, and by the officers and men of the fleet whose lives are concerned in the safety of the ships they will have to fight and manoeuvre in the presence of the enemy. No subject connected with Admiralty affairs has excited so much attention since the loss of the Captain, as this question of the safety of the Inflexible and the other vessels of her type, which has been under investigation for many months.

The report of the Committee now to hand, although it appears at first sight to acquit the Admiralty Constructors of all blunders regarding her stability, can only add to the apprehensions already felt concerning the safety of the vessel in action, and lead to further inquiry, for it corroborates all the statements of fact put forward by the *Times* and by Mr. Reed in condemnation of her.

The report in substance is a verdict for the Constructors of the Navy of "not guilty but don't do it again." When analyzed it will be seen that the recommendations of the Committee at the end of the report, regarding the type of vessel, are utterly inconsistent with the opinions they express as to the merits of the particular ship. They hesitate to condemn the Inflexible which is already built, and they equally shrink from any responsibility for her repetition. They consider that a just balance has been maintained in the design, so that out of a given set of conditions a good result has been obtained; yet they dwell upon "the great advantages which a further increase of beam would give to vessels of the Inflexible type," and they "bring under the very serious consideration of their lordships the necessity, before proceeding with the construction of more vessels of the type of the Inflexible, of thoroughly investigating whether by more beam their safety may not be largely increased without impairing their speed and efficiency."

As we have intimated above, this report when analyzed will be found to be as unsatisfactory, inconsistent, and disquieting a document as has ever been put forward on such a grave question.

We purpose examining it in detail, having regard to the real points at issue. In the first place does the Inflexible fulfill the conditions she was intended to fulfill? Does she depend for her stability and safety on her unarmored ends? Sufficient evidence now exists to settle these points once for all. The other question as to how far the unprotected ends are susceptible of damage under shell fire, has from the first been regarded as a matter of mere opinion until it is settled by artillery experiments.

Let us now see from the report of the Committee how the fact stands with reference to the dependence of the ship for stability on her unarmored ends. It will be seen in the answer to the second question, "As to whether there would be any risk of the ship capsizing if she were placed under the conditions mentioned in the previous paragraph [viz., the complete penetration and water-logging of the unprotected ends of the ship, and the blowing out of the whole of the stores and cork by the action of shell fire], supposing that the water ballast for which provision has been made, were admitted into the double bottom of the armored citadel,

or whether she would retain a sufficient amount of stability to enable such temporary repairs to be executed as would enable her to reach a port."

This is simply the condition, be it borne in mind, without the cork and canvas which the security of the ship was not to be dependent upon. The Committee say (and mark the guarded way in which it is put): "We find that under the extreme conditions assumed the ship, even without water ballast, would yet have stability, and would, therefore float upright in still water, and we are of opinion that the stability that she would have in that condition though small, is in consequence of the remarkable effects of free internal water in extinguishing rolling, sufficient to enable her to encounter with safety waves of considerable magnitude. The ship under these circumstances, however, would require to be handled with great caution. The admission of water as ballast increases the amount of stability, and is thus of advantage as against steady inclining forces, but on account of the deeper immersion it involves, it does not materially increase the range of the stability. When the immersion is such as largely to increase the depth of the water on the middle deck, it appears that the extinguishing effect of such water becomes less vigorous, so that in a seaway the ship would in the extreme condition be safer with a moderate than with a very large amount of water admitted as ballast."

"It must be clearly understood, however, that we should consider the ship in a very critical state if reduced to this condition in the presence of a still powerful enemy. Her speed and power of turning would be so limited as to prevent her being maneuvered with sufficient rapidity to insure her against being effectively rammed, or so as to avoid a well-directed torpedo, while the small residuum of stability she would possess would not avail to render such an attack other than fatal. Her guns would also have to be worked with great caution, and under restrictions imposed by the high angle to which their combined movements would in broadside firing heel the ship. We have already expressed our opinion that it is in a high degree improbable that the ship would be reduced to this condition, even in a protracted engagement. We think that the destruction implied by the extreme condition assumed, would be such that nothing effective could be done in the way of repair at sea under any circumstances."

Here everything is vague, general, and at first sight strikes the reader as being well weighed and cautious.

A significant light is thrown, however, upon the condition of the ship, as here referred to, in a paragraph on page 16, which we must quote, for it does not appear in the summary, and is likely to escape attention. It says: "The Indeflexible riddled and gutted, and without water ballast, going at the 7.24 knots, and turning in the circle of 1210 feet, in diameter, would require a righting lever or G Z of .13 ft., and as the value of G Z at her maximum stability in this condition is only .12 ft., she would on this supposition overset. It is, how-

ever, not to be expected that the ship under this condition could be driven at this speed, which with the Thunderer corresponded with 11.14 knots on the straight course."

They do not say, as we are quite sure our readers will say, that the ship having such a small fraction of the stability that proved too little for the Captain, and being in such a state that she would capsize by the action of her helm, would in all human probability go to the bottom in a sea-way, and is to all intents and purposes in the condition the *Times* and Mr. Reed said she would be in. The Committee, however, would only consider the ship in a very critical state if reduced to this condition *in the presence of a still powerful enemy!* as if any foe other than the ocean could be necessary to render such a case critical. Again, their apparent admissions that she would have to be handled with caution, and that she could not be manœuvred with sufficient rapidity to insure her against being effectively rammed, or so as to avoid a well-directed torpedo, are facts it is true, but they are facts put in such a way as to hide the real truth, and to avoid saying, what must force itself on the mind of any one, that the ship in that condition is hopelessly crippled and unsafe. Yet this is the condition in which oftener than in any other the safety was promised and guaranteed by the Constructors. How it is possible in view of the above figures for the Committee to say she has sufficient stability to enable her to encounter with safety waves of considerable magnitude we cannot conceive. Of this we may be quite sure, no one would dare to put it to the test in this country, by risking valuable lives on the faith of such an assertion. Captain Boys bases his opinion that the cork cannot be blown out, on the assumption that the vessel in the intact condition will not roll. The Committee are equally certain the Inflexible would not roll in her crippled condition. Doubtless when a ship is water-logged she is not so lively as ordinary vessels, but water-logged ships as a rule end by turning over and going to the bottom. It is moreover in the recollection of every one that it was claimed to be one of the chief merits of the Captain that she would not roll, and the constant repetition of the assertion did perhaps more than any other single cause to bind the present Constructors of the Navy to the dangers of that unfortunate ship. For this reason among others, we view with the utmost alarm the propagation of such ideas as that a vessel in a crippled condition, unable to turn at half speed without capsizing, and with a maximum righting lever of less than  $1\frac{1}{2}$  in., has stability sufficient to enable her to encounter with safety waves of considerable magnitude.

The Committee's recommendation to stop the construction of the other ships of the Inflexible type atones in some measure for their over-indulgence to her, and their discovery of the dangers existing in regard to her longitudinal stability will go far to rescue their inquiry from the charge of failure. Their statement that, "At present the inclining moment due to the running out of the guns is over 1,600 foot-tons, and becomes a serious element of

danger as the ship approaches the riddled and gutted condition," and their strong recommendation that the travel of the guns on their slides would be reduced to mitigate this evil as much as possible, show how little faith they have in their own recorded opinion that the ship would never be brought to a condition needing such precautions.—*Engineering*.

## BOOK NOTICES.

**THE PICTURE AMATEUR'S HAND-BOOK.** By PHILIPPE DARYL, B.A. London: Crosby Lockwood & Co. For sale by D. Van Nostrand. Price \$2.00.

This is a short treatise on the various schools of Painting, with some explanations of processes of painting, relining, restoring, &c.; all of which is briefly but well presented. This is followed by a dictionary of artists, giving in case of the most renowned a short biographical sketch.

It is a very convenient hand-book for that large class of visitors to picture collections, who would gladly know more about the pictures than they can glean from catalogues, or from any other source to which access is by any means convenient.

**ALBUM TO THE COURSE OF LECTURES ON METALLURGY, AT THE CENTRAL SCHOOL OF ARTS AND MANUFACTURES AT PARIS.** By S. JORDAN, C.E., M.I. Paris: J. Baudry.

The author explains in his preface that his needs, both as professor and engineer, prompted him to prepare a methodical and complete set of drawings which should exhibit the improved machinery now used in iron and steel manufacture. The object aimed in publishing the work, was to furnish engineers and managers of iron works with such examples of apparatus as should guide them in designing a new plant, or improving that already in use.

The work is divided into four parts as follows; viz; Part I, Fuel; Part II, Production of Pig Iron from the ore; Part III, Manufacture of Malleable Iron; Part IV, Manufacture of Steel.

The plates, one hundred and forty in number, form a large atlas, and are admirably designed for service as working drawings.

**THE SILVERSMITH'S HANDBOOK.** By GEORGE E. GEE. London: Crosby Lockwood & Co. For sale by D. Van Nostrand. Price \$3.50.

This is a thoroughly technical work designed for the Artisan only.

It aims at complete instruction in the different modes of alloying, and melting silver; its solders; preparation of imitation alloys; methods of working and prevention of waste.

The contents of the several chapters are as follows.

*Introductory*—Chap. 1, Silver; 2, Sources of Silver; 3, Assay of Silver ores; 4, Cupellation; 5, Alloys of Silver; 6, Various qualities of Silver; 7, Silver Solders; 8, Melting Silver; 9, Working Silver; 10, Enriching the surface of Silver; 11, Imitation alloys; 12, Economical processes; 13, Licences and duties (English); 14 and 15, Miscellaneous.

It is a well printed 12 mo. volume with 40 wood cuts.

**A MANUAL OF HEATING AND VENTILATION IN THEIR PRACTICAL APPLICATION.** By F. SCHUMANN, C. E. New York: D. Van Nostrand. Price \$1.50.

Now that the public mind is ready to assent to the urgent demand for sanitary reform, a practical guide to such improvement is clearly a widespread want. The need of pure air and proper temperature in our dwellings has been sufficiently urged, that is to that degree that all intelligent people assent to the main principles. The knowledge of how to accomplish the desired end in the most practicable way has not been so readily forthcoming.

This little Manual is designed to afford to Engineers and Architects the necessary formulas and tables for dimensions of heating pipes and ventilating flues of all kinds.

Under the heading Ventilation, the author gives the established formulas for amount of air supply with dimensions for supply and exit pipes, velocities of air currents, friction in the flues, &c.

Heating in like manner includes formulas and rules for obtaining the proper amount for any given space; for calculation of loss by radiation, by contact with air, and through the various bounding walls of the apartments. Also rules governing the use of Steam Pipes and Hot-Water Pipes.

Furnaces, Boilers and Chimneys receive a fair share of attention.

The Manual is useful in the hands of practical men only, and those who are familiar with the theoretical principles. It is well printed and enclosed in a substantial binding, suitable for a pocket reference book.

**MATTER AND MOTION.** By J. CLERK MAXWELL, LL.D., F.R.S. London: Society for Promoting Christian Knowledge. New York: D. Van Nostrand. Price 50 cts.

This, although one of the Manuals of Elementary Science, must not be regarded as presenting only the rudiments for beginners. A discussion of the fundamental ideas of physical forces by one of the foremost scientists, demands the attention of every teacher and student of physics.

The author's preface reads thus:

"Physical Science, which up to the end of the eighteenth century had been fully occupied in forming a conception of natural phenomena as the result of forces acting between one body and another, has now fairly entered on the next stage of progress—that in which the energy of a material system is conceived as determined by the configuration and motion of that system, and in which the ideas of configuration, motion, and force are generalized to the utmost extent warranted by their physical definitions.

To become acquainted with these fundamental ideas, to examine them under all their aspects, and habitually to guide the current of thought along the channels of strict dynamical reasoning, must be the foundation of the training of the student of Physical Science.

The following statement of the fundamental

doctrines of Matter and Motion is therefore to be regarded as an introduction to the study of Physical Science in general."

The subjects in order of treatment are: Motion Force; Properties of the Center of Mass of a Material System; Work and Energy; Recapitulation; The Pendulum and Gravity; Universal Gravitation.

**THE DRAINING OF LAKE FUCINO.** By ALEXANDER BRISSE & LEON DE ROTROU, translated by V. DE TIVOLI, JR. Rome: Propaganda-Press. For sale by D. Van Nostrand. Price \$25.00.

This bulky volume with its Atlas of elegant plates, presents a complete history of this extensive engineering operation. The work was carried out at the expense of Prince Alexander Torlonia. It was begun twenty-three years ago, and is just now approaching completion.

Many circumstances concur in imparting to this enterprise a special interest which similar works elsewhere can not claim.

Julius Cæsar first proposed to drain the lake. Claudius was the first to attempt it; his failure was repeated by Trajan, by Hadrian, and in later times by Frederic II, by Alphonso I of Aragon and by several sovereigns of Naples. It was given up as an impossibility till Prince Torlonia began in 1854 the operations which have just been crowned with success.

This famous lake which was somewhat elliptical in form, was 12.4 miles long and 6.8 miles in width, having an area of 173,000 acres. Having no outlet it was subject to great variations in level, and so was a constant source of anxiety to the inhabitants along its shores.

The tunnel through which the drainage was effected was 6887.5 yards in length, and was completed in 1869. The history of the present enterprise is the more interesting by reason of the fact that, incorporated with it, is the account of the work of the older engineers, much of which was revealed for the first time by the later excavations.

The entire work is given in both French and English, the two narratives appearing on opposite pages throughout. The plates are colored and form a large Atlas.

**GRAPHICAL STATICS.** By A. JAY DU BOIS, C.E., Ph. D. Second Edition, Revised and Corrected. New York: John Wiley & Son, Publishers, 1877.

This work is intended to introduce to the American public the new science of the graphical computation of statical problems as taught in Germany; of which it claims to set forth the theory and practice in a systematic manner.

The book, so far as we have observed, has been well received in the public prints; we are therefore led to examine it somewhat carefully.

It must be confessed that the courtesy which has been extended to the work, and for which the author thanks the public, has been due largely to the ignorance of graphical methods which prevails in this country. Had the work been published in Germany, in the German

language, it would have met a merited and a universal condemnation.

The book consists principally of literal translations selected from the principal German writers upon this subject, with extracts from certain English and American sources.

It was to be expected that in a treatise like this some attempt, at least, should be made to digest the material employed; and that care should be exercised that investigations such as occur in the subject of continuous girders for instance, should not be given more than once under forms which differ in notation only.

This, and the exceedingly curious and awkward arrangement of chapters, supplements and appendices, which is very striking, is the result of making a patchwork book with the scissors instead of the pen. From the same cause it happens that those bending moments which are considered positive in one part of the book are taken as negative elsewhere.

Again, at the middle of page 68 a certain expression is stated to be the equation of an ellipse. Bauschinger, from whom the author is translating at this point, adds, that the equation is expressed in terms of "line co-ordinates." Now we venture to assert that there is not an under-graduate student in our schools, such as this book was intended for, who is familiar with equations in line co-ordinates. It may even be supposed that the author, as he is yet quite a young man, is not in the habit of working with them. It may reasonably be supposed that he omitted the words from his translation because he did not understand them. It can hardly be that he supposed his readers more intelligent mathematicians than those for whom Bauschinger wrote his treatise. Now a curious consequence follows from this intentional omission, to wit, that the author does not recognize the ordinary equation of an ellipse when he sees it; for this equation he asserts to be that of an ellipse, meaning it, of course, in ordinary Cartesian co-ordinates, but it is not the equation of an ellipse when so interpreted. This degree of ignorance is unpardonable in a mathematical treatise.

The use of "center of action," sometimes for "center of gravity" and sometimes for "center of percussion," as well as the confined use of "moment of inertia" for what all English writers use another term, "products of inertia," or "moments of deviation," or some term which shall distinguish it from the proper moment of inertia, are suggestive of a defective training in elementary mechanics. There are several particulars in which the author has offended against the canons of good taste,—to use no stronger term.

One feature, which we must consider objectionable on the score of good taste, is this wholesale use of matter transferred bodily to the pages of the book without quotation marks. The author states continually that he is indebted for the substance of such and such an article or chapter to this or that writer; no reader, however, would be led to infer from such acknowledgements that the total indebtedness is really what it is. The author quotes so naturally that it seems to be a nearly unconscious process: compare the last half of the

first page of his *preface*, (which one would certainly expect to find original with the author) with the last paragraph but one on page XXXVI, translated from Weyrauch.

Another matter in which the author offends good taste is in the praise he bestows upon his own work. He is more self-conscious than any mathematical writer which we have had the fortune to read for many a day. We forgive such things in case of a great genius.

It is true that the author lays claim to certain applications of the frame-diagram method as being original with himself, but the cultivators of that method all agree that they can determine the pressures in any frame or part of a frame, such as he discusses, when the external forces are known, and they will hardly admit any claim except that the cases he discusses have not been directly copied from any one. Such a small claim need not be jealously guarded, or any parade made of it.

Another offence against good taste is in the English used. The style is inelegant, the grammar dubious, the punctuation abominable. The frequent mis-spelling of the word asymptotes by introducing a superfluous *s* is particularly trying. In certain passages no sense can be extracted from the sentences by the ordinary student. In short, the language lacks the clearness and exactness requisite for the treatment of such a subject, and is that in vogue with the newspaper correspondent of the period.

A last objection urged in behalf of good taste finds its text on the last pages of the book, where the author has seized the opportunity of attacking the opinions of a member of the American Society of Civil Engineers, which opinions the gentleman had advanced in a paper printed in the Transactions of that Society. Be the opinions correct or incorrect the author had no right to put the gentleman upon a perpetual pillory by ostentatiously calling him by name again and again with the intention of convicting him of error and discrediting him in the eyes of the readers of this book. It is not within the province of a systematic mathematical treatise, even though it include practical applications to inaugurate on its pages a personal controversy.

That part of the book which treats of flexible arches, stone arches, and the stiffening truss of suspension bridges is already superseded by the new and superior methods given during this year in a series of articles in VAN NOSTRAND'S ENGINEERING MAGAZINE by Professor Eddy. But aside from those articles the stone arch in particular is badly treated. The author, however, does not seem to have copied his treatment verbatim from any previous author. The method of trial for finding the curve of pressures is especially objectionable, and the principle stated at the bottom of page 317 from which its true position is to be found is completely false. The notation used in referring to the numerous figures is excessively irksome and wanting in the first elements of fitness, especially in Chapter II where the author is dealing with fundamental principles, which should be encumbered with as few difficulties as possible.

Another curious circumstance reveals itself in connection with the notation employed. It is evident that the author was unacquainted with Bow's book, to which he refers, until his own was about half completed, at which point he adopts Bow's notation. This is probably not the only instance in which the plan of the work was changed as the work progressed. Internal evidence points to large fractions of the work which were interjected as an after thought.

In what particular does the second edition differ from the first? For one thing, the author reluctantly modifies, in his second preface, the over enthusiastic assertions still retained in the body of the book respecting the economy of continuous girders for successive spans. We notice also that four pages of new matter are introduced at one point containing an illustrative example, and that a slight change is made at one other place. We have discovered no other alteration.

The author states that the second edition "has undergone a careful revision and correction, and no pains have been spared to render it free from typographical errors." A careful reading of the first edition has revealed the following errata in the coarse print on the first 160 pages in formulæ and letters referring to diagrams.

Page 64	line 28,	for $m'' L$	put $mn'' L$ .
" 66	" 7,	" $ox$	" $Ox$ .
" 66	" 8,	" $Ox$	" $Ox$ .
" 67	" 21,	" $xe \& ye$	" $xe^2 \& ye^2$ .
" 89	" 33,	" $P_1 MB$	" $AMB$ .
" 127	" 4,	insert	$H$ .
" 139	" 28,	" $NV'$	" $MV'$ .
" 144	" 22,	" $W_1 W$	" $W_0 W$ .
" 150	" 8,	" $BCT$	" $BGT$ .
" 155	" 15,	" $K$	" $P$ .
" 155	" 9,	" 80	" 95.
" 155	" 32,	" 75	" 95.

These are all but one of the errata of this important class found on these pages. Not one of them was corrected in this second edition. nor have we found any case of correction of a typographical error in the second edition. Numerous other errata of various kinds were found, not one of which has been corrected. For example there are several bad ones in the figures of which we may note that the kernel in Fig. 37, plate 11, is wrong side up. The Figs. are many of them taken bodily from German books, and some are copied incorrectly.

There are other defects in the work of lesser magnitude to which we shall not now call attention.

In the final paragraph of the author's first preface, which is quoted in the original German from Culmann, and also in the only passage in which the author's introduction differs from Weyrauch, he, as elsewhere, ranges his work beside that of Culmann and Bauehinger, the creators of modern Graphical Statics. The stripling on taking up his arms assumes the air of the aged warrior of a hundred battles.

This is sheer impudence, not only is this author not entitled to assume such a tone, but he has no right to speak as an authority upon the subject at all. He has made no investigations, he has earned no place in science except such as this book may give him, which is not an high one, for he has failed in it to assimilate and put in homogeneous form even the work of others.

## MISCELLANEOUS.

THE longevity of various trees has been stated to be, in round numbers, as follows: Deciduous cypress, 6,000 years; baobab tree of Senegal, 5,000; dragons' blood tree, 4,000; yew, 3,000; cedar of Lebanon, 3,000; olive, 2,500; oak, 1,600; orange, 1,500; Oriental plane, 1,200; Cabbage palm, 700; lime, 600; ivy, 600; ash, 400; cocoa nut palm, 300; pear, 300; apple, 200 years. The Brazil wine palm arrives at the age of 150 years; the Scotch fir gets its growth in about 100 years, and the balm of Gilead in about 50 years.—*Northwestern Lumberman*.

AN English writer, speaking of the different varieties of wood found in Australia, says: The blue gum of Van Dieman's Land is found abundantly in some of the forest districts, principally of the south, and is well known for its colossal size, so that it is superfluous to quote the statements made of its vast dimensions. Of the circumference of the stem instances are on record by which this tree ranks only second to the famous baobab from the Senegal. The experiments in Van Dieman's Land have shown that its strength and elasticity exceed generally those of all woods hitherto tested. It is equal in durability to oak and superior to it in size, and therefore highly esteemed for shipbuilding. Other *eucalypti* likewise claim attention on account of the beauty and durability their wood; in consequence of which qualities, one of them, from the south-eastern frontiers, received there the name of the mahogany tree. The wood of the *callistemon salignus*, although the tree is seldom of large dimensions, stands here perhaps unrivalled for hardness. The fragrant myall wood, so well adapted for delicate ornamental work, is obtained from *acacia malophylla* and some allied species of the Mallee desert. The well known blackwood, in some localities called lightwood, attains in the fern tree gullies an enormous size, and yields a splendid material for furniture, and, capable of a high polish, being also recommended for the finishing work of vessels. The myrtle tree of Sealer's cove and the Snowy river is also remarkable for its straight growth and its excellent wood. The Australian ever-green beech forms a noble tree, sometimes more than 100 feet high, of which the wood takes a beautiful polish. Omitting such kinds, as are chiefly known, we may mention as useful for ornamental work the sassafras wood, the lomatia wood, the tolonia tree, the musk wood, the iron wood, the zleria wood, the heath tree, and the Australian mulberry tree.

# VAN NOSTRAND'S

## ECLECTIC

# ENGINEERING MAGAZINE.

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### A NEW GENERAL METHOD IN GRAPHICAL STATICS.

BY HENRY T. EDDY, C. E., Ph. D., University of Cincinnati.

Written for VAN NOSTRAND'S MAGAZINE.

#### III.

#### EQUILIBRIUM POLYGON FOR PARALLEL FORCES.

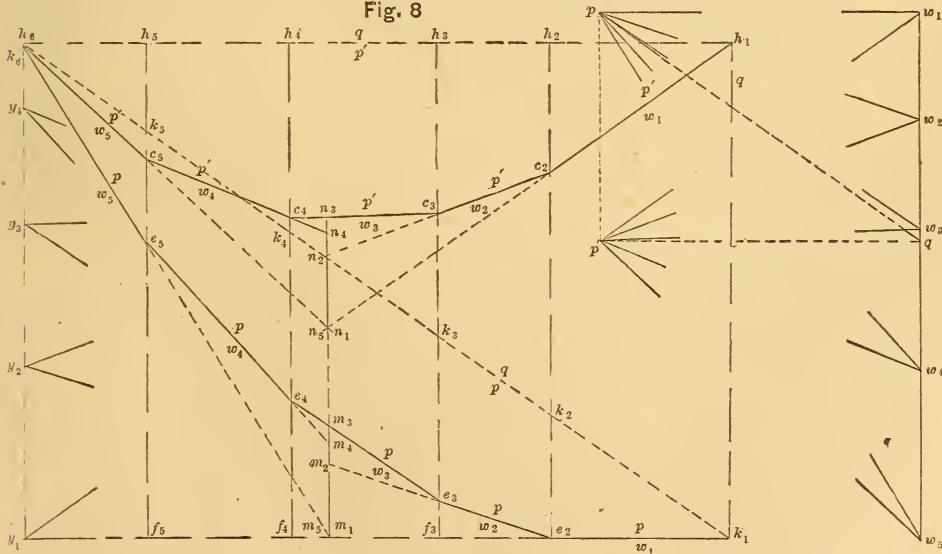
LET the system of parallel forces in one plane be four in number as represented in Fig. 8, viz:  $w_1, w_2, w_3, w_4$ , etc.,

acting in the verticals 2 3 4 5 of the force diagram on the left. Let the points of support be in the verticals 1 and 6.

The force polygon at the right re-

#### EQUILIBRIUM POLYGON.

Fig. 8



duces, in case of vertical forces, to a vertical line  $wv$ . Assume any arbitrary point  $p$  as pole of this force polygon, (or

weight line, as it is often designated) and, parallel to the rays of the force pencil at  $p$ , draw the sides of the equi-

brium polygon  $ee$ , in the manner previously described. Draw the closing line  $kk$  of this polygon  $ee$ , and parallel to it draw the closing ray  $pq$ ; then, as previously shown,  $pq$  divides the resultant  $w_1w_2$  at  $q$  into two parts which are the reactions of the supports. The position of the resultant is in the vertical  $mm$  which passes through the intersection of the first and last sides of the polygon  $ee$ , as was also previously shown.

Designate the horizontal distance from  $p$  to the weight line by the letter  $H$ . It happens in Fig. 8 that  $pw_1 = H$ , but in any case the pole distance  $H$  is the horizontal component of the force  $pq$  acting along the closing line.

Now by similarity of triangles

$$k_1e_2 (=h_1h_2) : k_2e_2 :: pw_1 : qw_1$$

$$\therefore H.k_2e_2 = qw_1.h_1h_2 = M_2,$$

the moment of flexure, or bending moment at the vertical 2, which would be caused in a simple straight beam or girder under the action of the four given forces and resting upon supports in the verticals 1 and 6.

Again, from similarity of triangles,

$$h_1h_3 (=k_1f_3) : k_2f_3 :: H : qw_1$$

$$h_2h_3 (=e_2f_3) : e_3f_3 :: H : w_1w_2$$

$$\therefore H(k_2f_3 - e_3f_3) = H.k_2e_3 = qw_1.h_1h_3 - w_1w_2.h_2h_3 = M_3$$

the moment of flexure of the simple girder at the vertical 3.

Similarly it can be shown in general that

$$H.ke = M,$$

i.e. that the moment of flexure at any vertical whatever (be it one of the verticals 2 3 4, etc., or not) is equal to the product of the assumed pole distance  $H$  multiplied by the vertical ordinate  $ke$  included between the equilibrium polygon  $ee$  and the closing line  $kk$  at that vertical.

From this it is evident that the equilibrium polygon is a moment curve, i.e. its vertical ordinate at any point of the span is proportional to the bending moment at that point of a girder sustaining the given weights and supported by simply resting without constraint upon piers at its extremities.

From this demonstration it appears that  $H.e_3f_3 = w_1w_2.h_2h_3$  is the moment of

the force  $w_1w_2$  with respect to the vertical 3; and similarly  $H.m_1m_2 = w_1w_2.e_2m_1$  is the moment of the same force with respect to the vertical through the center of gravity. Also,  $H.y_1y_2 = w_1w_2.h_2h_3$  is the moment of the same force with respect to the vertical 6.

Similarly  $m_1m_3$  is proportional to the moment of all forces at the right, and  $m_2m_6$  to all the forces left of the center of gravity, but  $m_1m_3 + m_2m_6 = 0$ , as should be the case at the center of gravity, about which the moment vanishes. From these considerations it appears that the segments  $mm$  of the resultant are proportional to the bending moments of a girder supporting the given weights and resting without constraint upon a single support at their center of gravity.

Let us move the pole to a new position  $p'$  having the same pole distance  $H$  as  $p$ , and in such a position that the new closing line will be horizontal, i.e.  $p'q$  must be horizontal.

One object in doing this is to furnish a sufficient test of the correctness of the drawing in a manner which will be immediately explained; and another is to transfer the moment curve to a new position  $cc$  such that its ordinates may be measured from an assumed horizontal position  $hh$  of the girder to which the forces are applied, so that the girder itself forms the closing line.

The polygon  $cc$  must have its ordinates  $hc$  equal to the corresponding ordinates  $ke$ , for

$$M = H.ke = H.hc$$

Also the segments of the line  $mm$  are equal to the corresponding segments of the line  $nn$  for similar reasons.

Again, as has been previously shown, the corresponding sides (and diagonals as well) of the polygons  $ee$  and  $cc$  intersect upon the line  $yy \parallel pp'$ .

These equalities and intersections furnish a complete test of the correctness of the entire construction.

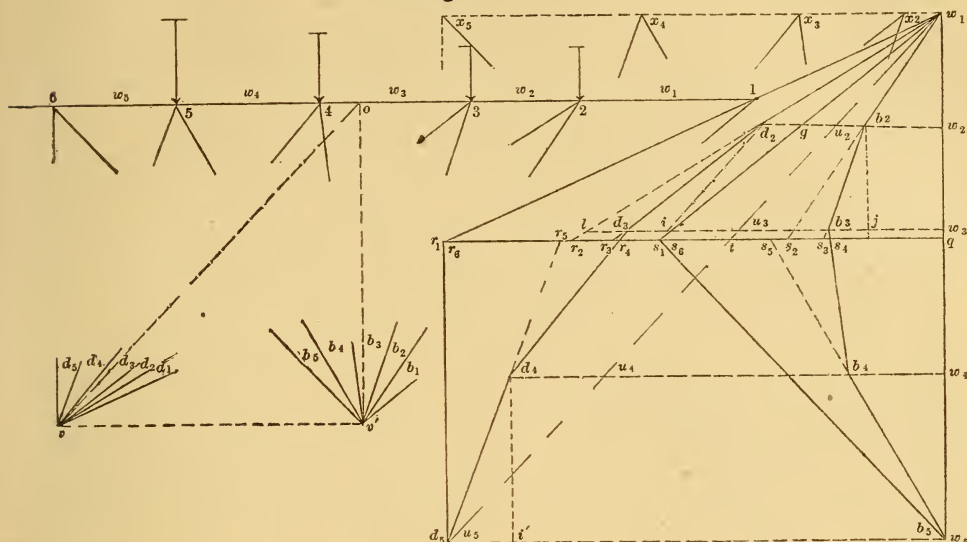
#### FRAME PENCIL FOR PARALLEL FORCES.

Let the same four parallel forces in one plane which were treated in Fig. 8 be also treated in Fig. 9, and let them be applied at 2, 3, 4, 5 to a horizontal girder resting upon supports at 1 and 6.

Use 16 as the frame line and choose any vertex  $v$  at pleasure from which to draw the frame pencil  $dd$ . Draw the

## FRAME PENCIL.

Fig. 9



force lines  $w_d$  parallel to the horizontal frame line 16, and then draw the equilibrating polygon  $dd$  with its sides parallel to the rays of the frame pencil  $dd$ .

As has been previously shown, if a resultant ray  $vo$  of the frame pencil  $dd$  be drawn from  $v$ , as represented in Fig. 9, parallel to the closing side  $uu$  of the equilibrating polygon, this ray intersects 16 at the point  $o$  where the resultant of the four given forces cuts 16.

Furthermore, the lines  $w_1r_1$  and  $d_1r_1$  parallel to the abutment rays  $v_1$  and  $v_6$  of the frame pencil intersect on  $rr$  the resolving line, which determines the point of division  $q$  of the reactions of the two supports, as was before shown.

Let the vertical distance between the vertex and the frame line be denoted by  $V$ .

In Fig. 9 it happens that  $v_6 = V$ . If the frame polygon is not straight, or being straight is inclined to the horizon,  $V$  has different values at the different joints of the frame polygon: in every case  $V$  is the vertical distance of the joint under consideration above or below the vertex. It will be found in the sequel that this possible variation of  $V$  may in certain constructions be of considerable use.

By similarity of triangles we have

$$12 : v_6 :: r_1r_2 : w_1q \\ \therefore V.r_1r_2 = w_1q.12 = M_2,$$

the bending moment of the girder at the point 2.

Draw a line through  $w_1$  parallel to  $v_3$ ; this line by chance coincides so nearly with  $w_1s_1$  that we will consider that it is the line required, though it was drawn for another purpose. Again, by similarity of triangles

$$13 : v_6 :: r_1s_1 : w_1q \\ 23 : v_6 :: d_2g (= r_3s_1) : w_1w_2 \\ \therefore V(r_1s_1 - r_3s_1) = V.r_1r_3 \\ = w_1q.13 - w_1w_2.23 = M_2$$

the bending moment at 3.

Similarly it may be shown that

$$V.r_1r_n = M_n,$$

i.e. that the moment of flexure at any point of application of a force to the girder is the product of the assumed vertical distance  $V$  multiplied by the corresponding segment  $rr$  of the resolving line.

The moment of flexure at any point of the girder may be found by drawing a line tangent to the equilibrating polygon (or curve) parallel to a ray of the frame pencil at that point, the intercept  $r_1r$  of this tangent is such that  $V.r_1r$  is the moment required.

Also by similarity of triangles

$$o2 : v_6 :: u_2d_2 : w_1w_2 \\ \therefore V.u_2d_2 = w_1w_2.o2 \\ o2 (= o3 + 32) : v_6 :: u_1l : w_1w_3$$

$$\begin{aligned} 32 : v6 :: d_3 l : w_2 w_3 \\ \therefore V(u_3 l - d_3 l) = V u_3 d_3 \\ = w_1 w_2 \cdot 02 + w_2 w_3 \cdot 03, \end{aligned}$$

i.e. the horizontal abscissas  $ud$  between the equilibrating polygon  $dd$  and its closing side  $uu$  multiplied by the vertical distance  $V$  are the algebraic sum of the moments of the forces about their center of gravity. The moment of any single force about the center of gravity being the difference between two successive algebraic sums may be found thus: draw  $d_2 i \parallel uu$ , then is  $V \cdot d_2 i$  the moment of  $w_1 w_2$  about the center of gravity, as may be also proved by similarity of triangles.

Again by proportions derived from similar triangles, precisely like those already employed, it appears that

$$V \cdot w_2 d_2 = w_1 w_2 \cdot 26$$

is the moment of the force  $w_1 w_2$  about the point 6. And similarly it may be shown that

$$V \cdot w_3 d_3 = w_1 w_2 \cdot 26 + w_2 w_3 \cdot 36$$

is the moment of  $w_1 w_2$  and  $w_2 w_3$  about 6.

Furthermore, as this point 6 was not specially related to the points of application 1 2 3 4, we have thus proved the following property of the equilibrating polygon: if a pseudo resultant ray of the frame pencil be drawn to any point of the frame line, then the horizontal abscissas between the equilibrating polygon and a side of it parallel to that ray, (which may be called a pseudo closing side), are proportional to the sum total of the moments about that point of those forces which are found between that abscissa and the end of the weight line from which this pseudo side was drawn. The difference between two successive sum totals being the moment of a single force, a parallel to the pseudo side enables us to obtain at once the moment of any force about the point, e.g. draw  $d_4 i' \parallel ww$ .  $\therefore V \cdot d_4 i'$  is the moment of  $w_4 w_5$  about 6.

Now move the vertex to a new position  $v'$  in the same vertical with  $o$ : this will cause the closing side of the equilibrating polygon (parallel to  $v'o$ ) to coincide with the weight line. The new equilibrating polygon  $bb$  has its sides parallel to the rays of the frame pencil whose vertex is at  $v'$ . If  $V$  is unchanged the abscissas and segments of

the resolving line are unchanged, and  $vv'$  is horizontal. Also  $xx \parallel vv'$  contains the intersections of corresponding sides and diagonals of the equilibrating polygon. These statements are geometrically equivalent to those made and proved in connection with the equilibrium polygon and force pencil.

In Figs. 8 and 9 we have taken  $H=V$ , hence the following equations will be found to hold,

$$\begin{aligned} k_2 e_2 = r_1 r_2, \quad k_3 e_3 = r_1 r_3, \quad k_4 e_4 = r_1 r_4, \text{ etc.} \\ m_1 m_2 = u_2 d_2, \quad m_1 m_3 = u_3 d_3, \quad m_1 m_4 = u_4 d_4, \text{ etc.} \\ y_1 y_2 = w_2 d_2, \quad y_1 y_3 = w_3 d_3, \quad y_1 y_4 = w_4 d_4, \text{ etc.} \\ m_2 m_3 = d_3 i, \text{ etc.}, \quad y_1 k_6 = d_6 i', \text{ etc.} \end{aligned}$$

By the use of *etc.* we refer to the more general case of many forces. From these equations the nature of the relationship existing between the force and frame pencils and their equilibrium and equilibrating polygons becomes clear. Let us state it in words.

The height of the vertex (a vertical distance), and the pole distance (a horizontal force) stand as the type of the reciprocity or correspondence to be found between the various parts of the figures.

The ordinates of the equilibrium polygon (vertical distances) correspond to the segments of the resolving line (horizontal forces), each of these being proportional to the bending moments of a simple girder sustaining the given weights, and resting without constraint upon supports at its two extremities.

The segments of the resultant line (vertical distances) correspond to the abscissas of the equilibrating polygon (horizontal forces) each of these being proportional to the bending moments of a simple girder sustaining the given weights and resting without constraint upon a support at their center of gravity.

The segments of any pseudo resultant line, parallel to the resultant, which are cut off by the sides of the equilibrium polygon, are proportional to the bending moments of a girder supporting the given weights and rigidly built in and supported at the point where the line intersects the girder; to these segments correspond the abscissas between the equilibrating polygon and a pseudo side of it parallel to the pseudo resultant ray.

The two different kinds of support which we have supposed, viz. support

without constraint and support with constraint, can be treated in a somewhat more general manner, as appears when we consider that at any point of support there may be, besides the reaction of the support, a bending moment, such as would be induced, for instance, when the span in question forms part of a continuous girder, or when it is fixed at the support in a particular direction. In such a case the closing line of the equilibrium polygon is said to be moved to a new position. It seems better to call it in its new position a pseudo closing line. The ordinates between the pseudo closing line and the equilibrium polygon are proportional to the bending moments of the girder, so supported. It is possible to induce such a moment at one point of support as to entirely remove the weight from the other, and cause it to exert no reaction whatever; and any intermediate case may occur in which the total weight in the span is divided between the supports in any manner whatever. When

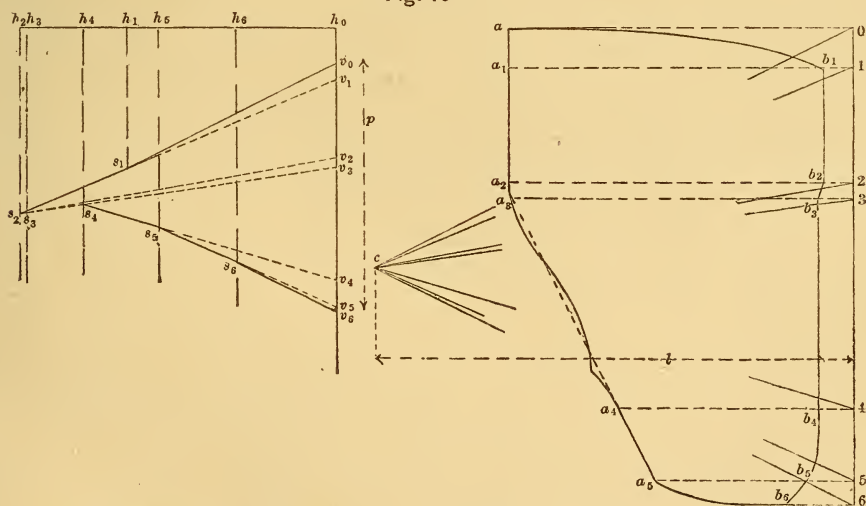
the weight is entirely supported at  $h_6$ , then  $y, e_2$  is the pseudo closing line of the polygon  $ee$ . In that case  $xx$  becomes the pseudo resolving line, and in general the ordinates between the pseudo closing line and the equilibrium polygon correspond to the segments of the pseudo resolving line, and are proportional to the bending moments of the girder. This general case is not represented in Figs. 8 and 9; but the particular case shown, in which the total weight is borne by the left pier, gives the equations

$$e_3 f_3 = w_1 x_2, e_4 f_4 = w_1 x_3, e_5 f_5 = w_1 x_4, \text{ etc.}$$

In order to represent the general case in which the weights, supported by the piers, are not the same as in the case of the simple girder, by reason of some kind of constraint, we propose to treat the case of the straight girder, fixed horizontally at its extremities; but it is necessary first to discuss the following auxiliary construction.

#### SUMMATION POLYGON.

Fig. 10



#### THE SUMMATION POLYGON.

In Fig. 10 let  $aabb$  be any closed figure of which we wish to determine the area. The example which we have chosen is that of an indicator card taken from page 12 of Porter's Treatise on Richard's Steam Indicator, it being a card taken from the cylinder of an old-fashioned paddle-wheel Cunarder, the Africa. The scale is such that  $a_1 b_1$  is 26.9 pounds per square inch and 06

parallel to the atmospheric line is the length of the stroke.

Divide the figure by parallel lines  $a_1 b_1, a_2 b_2, \text{ etc.}$  into a series of bands which are approximately trapezoidal. A sufficient number of divisions will cause this approximation to be as close as may be desired. The upper and lower bands may in the present case be taken as approximating sufficiently to parabolic areas. Let 06 be perpendicular to  $a_1 b_1$ ,

etc., then will 01, 12, etc., be the heights of the partial areas. Lay off

$$h_0 h_1 = \frac{2}{3} a_1 b_1, \quad h_0 h_2 = \frac{1}{2} (a_1 b_1 + a_2 b_2), \\ h_0 h_3 = \frac{1}{2} (a_2 b_2 + a_3 b_3), \text{ etc.}$$

then will these distances be the bases of the partial areas. Assume any point  $c$  at a distance  $l$  from 06 as the common point of the rays of a pencil passing through 0, 1, 2, etc.; and draw the parallels  $hs$ : then from any point  $v_0$  of the first of these make  $v_0 s_1 \parallel c0$ , and  $s_1 s_2 \parallel c1$ ,  $s_2 s_3 \parallel c2$ , etc.

The polygon  $ss$  is called the summation polygon, and has the following properties.

By similarity of triangles

$$l : 01 :: h_0 h_1 : v_0 v_1, \quad \therefore 01 \cdot h_0 h_1 = l \cdot v_0 v_1$$

is the area of the upper band. Similarly  $12 \cdot h_1 h_2 = l \cdot v_1 v_2$  is the area of the next band, and finally

$$06 \cdot o(h_0 h) = l \cdot v_0 v_6 = lp$$

is the total area of the figure.

In the present instance we have taken  $l=06$ , the length of stroke, consequently  $p$  is the average pressure during the stroke of the piston, and is 21.25 pounds, which multiplied by the volume of the cylinder gives the work per stroke.

This method of summation, which obtains directly the height  $p$  of a rectangle of given base  $l$  equivalent in area to any given figure, is due to Culmann, and is applicable to all problems in planimetry;

it is especially convenient in treating the problems met with in equalizing the areas of profiles of excavation and embankment, and is frequently of use in dividing land. It is much more expeditious in application than the method of triangles founded on Euclid, and is also, in general, superior to the method of equidistant ordinates, whether the partial areas are then computed as trapezoids or by Simpson's Rule; for it reduces the number of ordinates and permits them to be placed at such points as to make the bands approximate much more closely to true trapezoids than does the method of equidistant ordinates.

#### GIRDER WITH FIXED ENDS.

It is to be understood that by a girder with fixed ends, we mean one from which if the loading were entirely removed, without removing the constraint at its ends, there would be no bending moment at any point of it, and, when the loading is applied to it the supports constrain the extremities to maintain their original direction unchanged, but furnish no horizontal resistance. Under those circumstances the girder may not be straight, and may not have its supports on the same level, but it will be more convenient to think of the girder as straight and level, as the moments, etc., are the same in both cases.

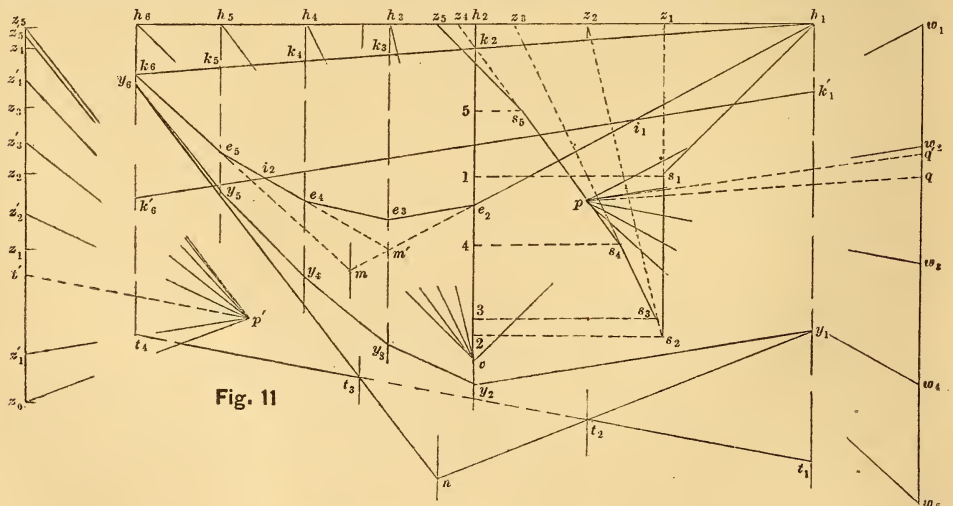


Fig. 11

Suppose in Fig. 11 that any weights  $w_1, w_2$ , etc. are applied at  $h_2, h_3, h_4, h_5$ , to a girder which is supported and fixed horizontally at  $h_1$  and  $h_6$ . With  $p$  as the

pole of a force pencil draw the equilibrium polygon  $ee$  as in Fig. 8. The resultant passes through  $m$ .

It is shown in my New Constructions in Graphical Statics, Chapter II, that the position of the pseudo closing line  $k'k'$ , in case the girder has its ends fixed as above stated, is determined from the conditions that it shall cut the curve  $ee$  in such a way that the moment area above  $k'k'$  shall be equal to that below  $k'k'$ , and also in such a way that the center of gravity of the new moment area shall be in the same vertical as the original moment area.

To find the center of gravity of the moment area  $ek$ ; determine the areas of the various trapezoids of which it is composed by help of the summation polygon  $ss$ . In constructing  $ss$  we make  $h_2l = k_2e_2$ ,  $h_2l_2 = k_2e_2 + k_3e_3$ , etc., and using  $v$  as the common point of the pencil we shall have  $h_2v \cdot h_1z_6$  = twice the area of the moment area. We have used the sum of the two parallel sides of each trapezoid instead of half that quantity for greater accuracy.

Now lay off from  $z_6$ ,  $z_6z_1 = h_1z_1$ ,  $z_6z_2 = h_1z_2$ , etc., as a weight line and assume the pole  $p'$ .

Of the triangle  $h_1h_2e_2$ , one-third rests at  $h_1$  and two-thirds at  $h_2$ ; make  $z_6z_1' = \frac{1}{3}z_6z_1$ , it is the part of the area applied at  $h_1$ . Of the area  $h_2e_2e_3h_3$ , one half, approximately, rests at  $h_2$  and one half at  $h_3$ . Bisect  $z_1z_2$  at  $z_2'$ , then  $z_1'z_2'$  rests at  $h_2$ . Bisect each of the other quantities  $z_2z_3$ , etc. except  $z_4z_6$ , in which make  $z_6z_6' = \frac{1}{3}z_6z_4$ . With the weights  $z'z'$  so obtained, construct the second equilibrium polygon  $yy$ , which shows that the center of gravity of the moment area is in the vertical through  $n$ . There is a balancing of errors in this approximation which renders the position of  $n$  quite exact; if, however, greater precision is desired determine the centers of gravity of the trapezoids forming the moment area, and use new verticals through them as weight lines, with the weights  $zz$  instead of the weights  $z'z'$ .

Draw verticals which divide the span into three equal parts,—they cut  $ny_1$  and  $ny_6$  at  $t_2$  and  $t_3$ , and draw  $p't' \parallel t_2t_3$ . Then is  $t_1t_2nt_3t_4$  an equilibrium polygon due to the force  $z_6z_6'$  applied at  $n$ , and to the forces  $z_6t_2'$  and  $t_3z_6$  applied at  $t_2$  and

$t_3$  respectively. As explained when treating this matter in the New Constructions in Graphical Statics,  $z_6t_2'$  and  $t_3z_6$  are proportional to the bending moments at the extremities of the fixed girder. In this case, since we have taken  $h_2v = \frac{1}{2}h_1h_6$ , we find that  $h_1k_1' = \frac{1}{2}z_6t_2'$ , and  $h_3k_6' = \frac{1}{2}t_3z_6$  are the end moments, and they fix the position of the pseudo closing line. Draw  $p'q' \parallel k'k'$  then are  $w_1q'$  and  $q'w_6$  the reactions of the piers. The pseudo resultant is at  $m'$ .

To obtain the same result by help of a frame pencil, let Fig. 12 represent the same weights applied in the same manner as in Fig. 11. Choose the vertex  $v$ , and draw the equilibrating polygon  $dd$ , etc. as in Fig. 8. Make  $h_2l = r_1r_2$ ,  $h_2l_2 = r_1r_2 + r_1r_3$ , etc., since these quantities are proportional to the bending moments as previously shown. With  $v$  as the common point of the rays of a pencil, find  $h_1z_6$  by the help of the summation polygon  $ss$  just as in Fig. 11.

Lay off the second weight line  $z_6z_1'$ , etc., just as in Fig. 11, and with  $v$  as vertex construct the second equilibrating polygon  $xx$ . Then as readily appears  $vn \parallel z_6x_6$  determines  $n$  the center of gravity of the moment area. Make  $z_6x_6 \parallel vt_2$  and  $x_6x_6' \parallel vt_3$ ; if  $t_2$  and  $t_3$  divide the span into three equal parts, then the horizontal through  $x_6$  fixes  $t'$  corresponding to  $t'$  in Fig. 11.

To find the position of the pseudo resolving line and its segments proportional to the new bending moments, lay off  $r_1j = \frac{1}{2}(t'z_6 - z_6t')$  the difference of the bending moments at the ends, and make  $j'r_6' \parallel r_1w_1$  and prolong  $u_6r_6$  until they meet at  $r_6'$  which is on the pseudo resolving line. Then lay off  $r_1r_6' = \frac{1}{2}z_6t_2'$  and  $r_6'r_6' = \frac{1}{2}t_3z_6'$  upon this pseudo resolving line  $r'q'$ , then  $r'r_2'$ ,  $r'r_3'$ , etc., are the bending moments when the girder is fixed at the ends. For by similarity of triangles

$$h_1h_6 : V :: r_1r_6' : qq', \\ \therefore h_1h_6 \cdot qq' = V \cdot r_1r_6',$$

is the moment, and  $qq'$  is the weight which is transferred from one support to the other by the constraint, hence  $r'q'$  is the correct position of the pseudo resolving line. Thence follows the proof that the bending moments are proportional

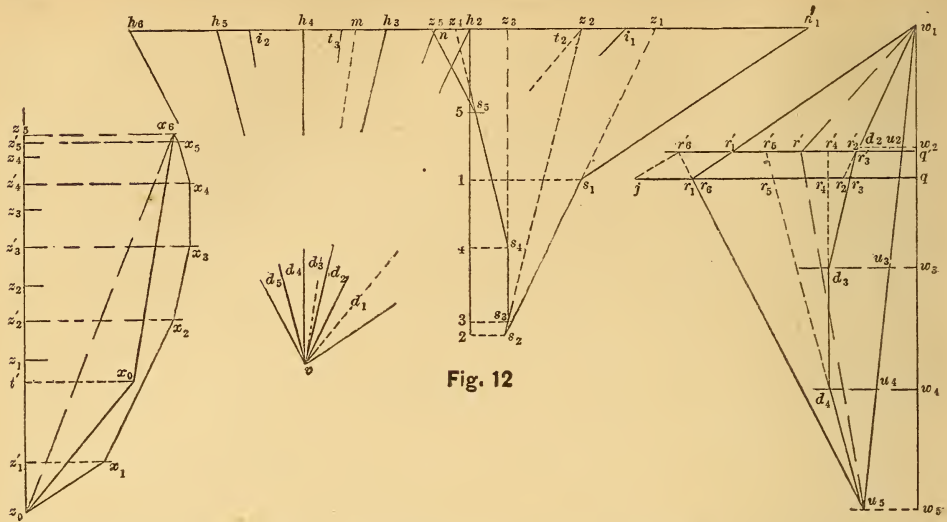


Fig. 12

to intercepts upon this line in a manner precisely like that employed in Fig. 9.

Again, draw  $vi_1 \parallel w_1r'$  and  $vi_2 \parallel u_2r'$ , then are  $i_1$  and  $i_2$  the points of inflexion of the girder when the bending moment vanishes, being in reality points of support on which the girder could simply rest without constraint and have the pseudo resultant in that case as the true resultant.

In Figs. 11 and 12 we have taken  $H=V$ , consequently the new moments can be directly compared, the ordinates  $k'e$  being equal to the corresponding segments  $r'r$ .

Apparently in this example Fig. 12 presents a construction somewhat more compact than that of Fig. 11, it is certainly equally good.

It remains to remark before proceeding to further considerations of a slightly different character, that we owe to the genius of Culmann\* the establishment of the generality of the method of the equilibrium polygon.

He adopted the funicular polygon, some of whose properties had long been known, and upon it founded the general processes and methods of systematic work which are now employed by all.

Furthermore it should be stated that parallelograms of forces were compounded and applied in such a way as to give rise to a frame pencil and equilibrating polygon by the illustrious Poncelet† who by their use determined

the centers of gravity of portions of the stone arch. Whether he recognized other properties besides the simple determination of the resultant of parallel forces, I am not informed, as my knowledge of Poncelet's memorial is derived from so much of his work as Woodbury\* has incorporated in his graphical construction for the stone arch.

So far as known, the method has been advanced by no one of the numerous recent writers upon Graphical Statics which would certainly have been the case had Poncelet established its claim to be regarded as a general method. I think the method of the frame pencil may now fairly claim an equal generality and importance with that of the equilibrium polygon.

HERR HIRN has been conducting a series of experiments in Germany on the comparative strength of wood and cast iron in their different applications, and finds that in a great number of cases the former has the advantage. Professor Hirn finds the strength of wood to be in direct ratio to its density, and this strength is increased by immersing the pieces of wood in linseed oil, heated from 185 deg. to 212 deg. Fah., and letting the wood thus immersed remain for two or three days, or until partially saturated.

\* Graphische Statik. Zurich, 1866.

† Memorial de l'officier Genie. No. 12.

\* Treatise on the Stability of the Arch. D. P. Woodbury, New York, 1858.

## THE ANEROID BAROMETER, ITS CONSTRUCTION AND USE.

Compiled for VAN NOSTRAND'S MAGAZINE.

## II.

La Place's formula which includes terms derived from the consideration of these conditions is obtained as follows :

Suppose a portion of the atmosphere included between two stations at different altitudes to be divided into very thin laminæ.

Let  $z$  be the distance of one of these from the surface of the globe and  $dz$  its thickness.

Let  $P$  be the pressure upon a unit of surface upon the lower side of this layer; and  $W$  the weight per cubic meter of the air at this pressure.

Then the pressure on the upper side will be less than  $P$  by an amount equal to the weight of a column of air whose base is a unit and height is equal to  $dz$ . Whence

$$dP = -Wdz. \quad (1)$$

If  $W_0$  be the weight of a cubic meter of air at the temperature  $0^\circ\text{C}$  and a barometric pressure of 0.76, the weight of this same volume at pressure  $P$  and temperature  $\theta$  would be

$$= W_0 \frac{P}{0.76} \cdot \frac{1}{1 + \alpha\theta}$$

$\alpha$  being the coefficient of dilatation of air which is here taken at .004 in consequence of the constant pressure of watery vapor.

This expresses the weight at the surface of the globe. If transferred to the height  $z$ , the weight would be diminished in the ratio of the squares of the distances from the center of the earth. We should then have

$$W = W_0 \cdot \frac{P}{0.76} \cdot \frac{1}{1 + \alpha\theta} \cdot \frac{R^2}{(R+z)^2}$$

Substituting in equation 1, dividing by  $P$  and integrating between  $0$  and  $z$ , we get, by calling the pressure at the lower station  $P_0$ ,

$$\log \frac{P_0}{P} = \frac{W_0 R}{0.76 \cdot (1 + \alpha\theta)} \cdot \frac{z}{R+z}$$

the logarithm being Napierian.  
From this we obtain

$$z = \frac{0.76 (1 + \alpha\theta)}{W} \log \frac{P_0}{P} \left(1 + \frac{z}{R}\right)$$

But the pressures  $P_0$  and  $P$  are in direct ratio of the mercury columns which we will designate by  $h_0$  and  $h$ . These columns also vary in weight in accordance with the law of inverse squares of distance from the earth's center, so that

$$\frac{P_0}{P} = \frac{h_0}{h} \cdot \frac{(R+z)^2}{z^2} = \frac{h_0}{h} \left(1 + \frac{z}{R}\right)^2$$

Substituting in the value of  $z$ , we have

$$z = \frac{0.76 \cdot (1 + \alpha\theta)}{W_0} \left\{ \log \frac{h_0}{h} + 2 \log \left(1 + \frac{z}{R}\right) \right\} \times \left(1 + \frac{z}{R}\right)$$

But as  $z$  is so very small compared with  $R$ , we may replace  $\log \left(1 + \frac{z}{R}\right)$  by  $\frac{z}{R}$ .

Also  $\frac{z^2}{R^2}$  may be neglected.

We shall then have

$$z = \frac{0.76 (1 + \alpha\theta)}{W_0} \left\{ \left(1 + \frac{z}{R}\right) \log \frac{h_0}{h} + \frac{2z}{R} \right\}$$

The weight  $W_0$  refers to the height  $h_0$ , the lower of the two stations. At the surface of the earth, this weight would be greater in the ratio of  $\frac{(R)^2}{(R-h)^2}$ . But as  $h$  is always small compared with  $R$  this correction may be neglected.

But there is another of more importance which should be taken into account. On account of the spheroidal form of the globe weight varies with the latitude. If  $G$  represent the weight of a body at latitude  $45^\circ$ , then at any other latitude  $l$  its weight is found by multiplying  $G$  by

$$1 - .00265 \cos. 2l$$

This factor is to be applied to  $W_0$  in the formula. This is accomplished by multiplying the above value of  $z$  by  $1 + .00265 \cos. 2l$ .

In order to simplify the expression we will substitute  $\theta$  the mean between the temperatures of the upper and lower

stations, designated by  $t_0$  and  $t$ . The factor  $1 + a\theta$  then becomes -

$$1 + \frac{2(t_0 + t)}{1,000} \text{ since as } a = .004;$$

and the value of  $z$  may be written

$$z = \frac{0.76}{W_0} \left\{ 1 + \frac{2(t_0 + t)}{1000} \right\} \times \left\{ \left( 1 + \frac{z}{R} \right) \log \frac{h_0}{h} + \frac{2z}{R} \right\} \times (1 + .00265 \cos. 2l)$$

If  $M$  be used to represent the modulus of the Napierian logarithms we may write

$$z = \frac{0.76}{MW_0} \left\{ 1 + \frac{2(t_0 + t)}{1000} \right\} \times \left\{ \left( 1 + \frac{z}{R} \right) \log \frac{h_0}{h} + \frac{2Mz}{R} \right\} \times (1 + 0.00265 \cos. 2l)$$

in which the logarithms are of the common kind.

This is La Place's formula.  $h$  in the expression is not the barometric height directly observed at the upper station, but this height reduced to the temperature of the lower station.

The value of  $\frac{0.76}{MW_0}$  has been determined by trial of the formula upon known altitudes. Ramond in his survey of the Pyrenees determined its value to be 18336.

The unknown term  $z$  in the second member is determined by successive approximations.

The first value being

$$z_1' = 18336 \log. \frac{h_0}{h} \text{ (meters)}$$

This being substituted, we may have

$$z_2 = z_1 + \frac{2(t_0 + t)}{1000} z_1$$

Finally, these being substituted in the above value of  $z$  we get

$$z_1 = 18336 \log. \frac{h_0}{h} + \frac{2(t_0 + t)}{1000} z_1 + z_2 .00265 \cos. 2l + (z^2 + 2M. 18336) \frac{z^2}{R}$$

The terms of this formula are generally reduced to tabular form for practical use.

Guyot's formula which is derived from this, reducing meters to feet and the constants depending on temperature being changed to accord with Fahrenheit's scale, is

$$z = 60158.6 \log. \frac{h_0}{h} \left\{ \left( 1 + \frac{t_0 + t - 64}{900} \right) (1 + .00260 \cos. 2l) \left( 1 + \frac{z + 52252}{20886860} + \frac{s}{10443430} \right) \right\}$$

The three terms after the first are the corrections. The first being that for the temperature at the two stations. The second is the correction for the force of gravity depending on the latitude.

The third contains, first the correction for action of gravity on the mercury column at the elevation  $z$ , and second a correction required for decrease in density of air owing to decrease in action of gravity at the greater elevation. The factor  $s$  being the approximate difference in altitude of the stations.

Plantamour's formula, which has been much used, differs slightly from Guyot's. The first coefficient is 60384.3. The denominator of temperature term is 982.26 and a separate correction is used for humidity of the air.

To use either of these formulas elaborate tables are necessary, of which those prepared by Lieut. Col. Williamson\* are the most elaborate.

For the Aneroid in ordinary practice, formulas of much less complexity may be profitably used. The corrections depending upon the gravity of the mercury column would, in any case, be omitted. The other corrections may in very nice work be retained. But a correction depending on the effect of changes of temperature on the metallic work of the instrument should be carefully remembered. First class Aneroids claim to be *compensated*, but a greater portion will need a correction which the purchaser can determine for himself, by subjecting the instrument to different temperatures while the pressure remains constant.

Approximate formulas to be used

\* The Use of the Barometer on Surveys and Reconnoissances. By R. S. Williamson. New York: D. Van Nostrand. London: Trubner & Co.

when no tables are at hand have been presented by various writers.

In *Engineering* for October, 1877, we get the following:

"For measuring heights not exceeding a quarter of a mile above the sea by means of the Aneroid, Admiral Fitzroy proposed the following method. Divide the difference between the readings at the lower and upper station by 0.011, the quotient is the approximate height in feet. Thus, Aneroid reading at:

Lower station..... 30.385 inches.  
Upper station..... 30.025 "

Difference.....  $.360 \div .0011 = 327$  ft.

Another very simple rule was proposed by Mr. R. Strachan in the *Horological Journal* for 1866. Read the Aneroid to the nearest hundredth of an inch; subtract the reading at the upper station from that at the lower, neglecting the decimal point; multiply the difference by 9; the product is the elevation in feet. Example:

Lower station..... 30.25  
Upper station..... 29.02

$123 \times 9 = 1107$  ft.

The following short method has been proposed for altitudes not much exceeding half a mile above the sea, where extreme accuracy may not be desired. Take from the subjoined Table the value corresponding to the mean reading of the Aneroid at the upper and lower stations, and the mean temperature (which may be guessed at when not observed); then divide the difference of the Aneroid readings by it; the quotient will be the height in feet.

Mean of Aneroid at Two Sta- tions.	Mean temperature.		
	25 deg.	50 deg.	75 deg.
in.			
27	.00104	.00099	.00094
28	.00108	.00103	.00098
29	.00112	.00107	.00102
30	.00115	.00110	.00105

(Example on following page.)

Mr. J. M. Heath has proposed the following short method: When the mean temperature at the stations is  $\left\{ \begin{array}{l} \text{less} \\ \text{greater} \end{array} \right\}$

Example:

Aneroid at base of Ben Lomond... 29.890 } mean temperature  
Aneroid at summit of Ben Lomond. 26.656 } of the air 50 deg.

Difference.. 3.234

= quotient 3110 ft.

Divisor found in Table..... .00104

than 62 deg.  $\left\{ \begin{array}{l} \text{increase} \\ \text{decrease} \end{array} \right\}$  both the readings of the Aneroid at the rate of 1 inch for every 15 deg.  $\left\{ \begin{array}{l} \text{below} \\ \text{above} \end{array} \right\}$  62 deg., or 0.2 for every 3 deg. The difference of the tabular numbers opposite these reduced readings is the vertical altitude in feet.

Aneroid.	No.	Aneroid.	No.
30.9	4824 90	28.1	2170 99
30.5	4460 91	27.8	1870 100
30.2	4184 92	27.5	1567 101
29.9	3905 93	27.3	1363 102
29.6	3623 94	27.0	1054 103
29.2	3243 95	26.7	742 104
28.9	2955 96	26.5	532 105
28.7	2761 97	26.2	214 106
28.4	2467 98	26.0	0 107

Example: The last given, worked by this method.

Base..... 29.890 summit 26.656  
Temp. 62 deg. - 50 deg.  
= 12, gives +..... .800 + .800

Tabular No..... 30.690 27.456  
Difference.... 4633 1522  
3111 ft.

All the foregoing rules are mere simplifications of Laplace's formula, but are useful to travelers, tourists, military and civil engineers who require to obtain rapid results from their contouring observations.

Still another simple rule is based on the fact that in the logarithmic term of the complete formula the Napierian logarithm of  $\frac{H}{h} = 2 \frac{H-h}{H+h}$  very nearly. Applying to the result thus obtained a tem-

perature correction for an average of 55° F. we obtain for an approximate value of difference of level between two observed stations.

$$D = 55032 \frac{H-h}{H+h}.$$

A formula which we find in an excellent paper by Gen. Theo. G. Ellis, presented to the Am. So. of Civil Engineers, in January 1871, and credited to Sir George Schuckburg.

Gen. Ellis suggests a modification of this, which the writer has found to give good results recently in some topographical surveys in the Catskill Mountains.

The form proposed is:

$$D = 55000 \frac{H-h}{H+h}$$

This gives the altitude very nearly when the average temperature of the upper and lower stations is 55°F. When it is higher add  $\frac{1}{500}$  of the calculated value for each degree above 55°, and subtract a like amount when the temperature is lower.

In the above formula  $H$  and  $h$  are the barometric heights at the lower and upper stations respectively, and  $D$  is the difference in altitude in feet.

Prof. Airy's formula is, omitting the more refined corrections of the formulas of La Place and Plantamour,

$$D = 60500 (\log. H - \log. h) \left( 1 + \frac{T+t-64}{964} \right)$$

Gen. Ellis offers as a convenient modification.

$$D = 60000 (\log. H - \log. h) \left( 1 + \frac{T+t-60}{900} \right)$$

The direct use of a formula being in general too laborious to be satisfactory, tables for facilitating the computations have been constructed. Of these there are many sets by different authors. Guyot's, Williamson's and Loomis's are well known and have been much used.

Many observers however desire to avoid even the amount of labor which such tables and formulas involve. To meet such a want, in 1867 Prof. Airy prepared a table for the use of the manufacturers of Aneroids, to be employed in the graduation of a circle of feet measures, concentric with the circle of inches.

This table extended by interpolation is given further on.

When the Aneroid has a *fixed circle of feet* engraved on it in accordance with this table, the approximate height is obtained by subtracting the reading in feet at the lower station from that at the upper.

If the average temperature is 50° Fahrenheit no correction is required. But in all cases observe the temperatures at both stations. Add them together; if the sum is greater than 100°, *increase* the height by  $\frac{1}{1000}$ th part for every degree above 100°. If the sum of the temperatures is less than 100°, then *diminish* the estimated height by  $\frac{1}{1000}$ th part for every degree below 100°.

It is evident from the construction of the table that it may be used with Aneroids which have no scale of feet. A correct graduation of the scale corresponding to the mercurial barometer is all that is required. The corresponding heights in feet taken from the table are then to be used as above.

The makers of Aneroids have endeavored to improve on Prof. Airy, and have made his scale of feet movable, "showing on the dial, without the aid of pencil and tables the height of any given place above another." The observer is directed to bring the 0 point of the movable rim or scale to the point of the index when at the lower station, then at the upper station the altitude is indicated at once by the pointer.

The use of such a scale leads only to rough approximations, as it is based on the assumption that certain differences of pressure correspond at all heights with the same differences of elevation. The writer of a recent article in *Engineering* (Oct. 1877) says of these scales:

"However advantageous it might be to have so simple a means of observing heights, truth compels the assertion that this movable scale is unscientific and misleading. Its effect is to make the second differences of barometric inches, for equal elevations, a decreasing series instead of an increasing one; in fact, to reverse the character of the serial differences. The heights are only likely to be correct when the scale is adjusted to 30 inches at the sea level. As the adjustment is made further from 30, so the elevations are given more and more in-

accurate, always in defect as the heights increase. Thus from 26, at zero, to 15, it gives 12,300 feet, being 2000 in defect from 16, at zero, to 15 1000 feet: or nearly 700 in defect! It is evident that this movable scale is a gross misconception, and must generally give erroneous measurements."

Mr. Rogers Field, C.E.; in 1873, applied the movable scale to the Aneroid so as to covert it from being a source of inaccuracy into an aid towards accuracy. He employs the altitude scale proposed by Sir G. Airy for temperature  $50^{\circ}$  but he makes it movable so as to adjust it for any other temperature. The shifting of the scale into certain fixed positions is made to answer the same purpose as if the original scale were altered to suit various temperatures of the air. In the *Journal of the Meteorological Society* for 1874, January, Mr. Field says:

"The object aimed at in designing this improved form of Aneroid was, to simplify the correct determination of altitudes in cases such as ordinarily occur in England, and the instrument is therefore arranged to suit moderate elevations, say of 2000 feet and under, and is not intended for more considerable heights.

"The Aneroid is graduated for inches in the usual way on the face, but the graduation only extends from 31 inches to 27 inches so as to preserve an open scale. The outer movable scale is graduated in feet for altitudes, and this graduation is laid down by fixing the movable scale with the zero opposite 31 inches. This is the normal position of the scale and it is then correct for a temperature of  $50^{\circ}$ . For temperatures below  $50^{\circ}$  the zero of the scale is moved below 31 inches for temperatures above  $50^{\circ}$  the zero of the scale is moved above 31 inches. The exact position of the scale for different temperatures has been determined partly by calculation and partly by trial, and marked by figures engraved on the outside of the Aneroid. In order to insure the altitude scale not being shifted after it has once been set in its proper position there is a simple contrivance for locking it in the various positions. This consists of a pin, which fits into a series of notches on the outside of the ring carrying the glass. By slightly raising the glass it is freed from this locking pin, and can be

turned until the figures corresponding to the air temperature are opposite to the pin, when the glass should be depressed so as to relock it, and the scale becomes correct for that temperature. The altitudes are in all cases determined by taking two readings one at each station, and then subtracting the reading at the lower station from that at the upper.

"It will be seen from the foregoing description that the movable scale of the instrument requires to be set for temperatures before taking any observations, and must not be shifted during the progress of the observations.

"This may appear at first sight as a defect inasmuch as the temperature of the air may alter during the progress of the observations; but practically it will not be found to be any drawback in the case of moderate altitudes, as small variations of temperature will not appreciably affect the result. A variation of  $5^{\circ}$  of temperature gives only about 1 per cent. variation in the altitude, an amount that would under ordinary circumstances be inappreciable, so that as long as the temperature does not vary during the course of the observations more than  $5^{\circ}$  from that at which the instrument is set, the results may be accepted as correct, and, generally speaking, even a greater variation than this, say  $6^{\circ}$  or  $8^{\circ}$ , would be practically of no importance. Of course, if it should be found at any time that the temperature has varied considerably during the course of the observations from that at which the instrument was set, this variation can be allowed for by calculation in the usual way."

The principle of allowing for variation of temperatures of the air by shifting the altitude scale is not theoretically accurate, but sufficiently so for practical purposes. For altitudes within the range of the instrument (say 3000 feet and under) and temperatures between  $30^{\circ}$  and  $70^{\circ}$ , the maximum error from using the shifted scale, instead of the calculation, is only 2 feet, which is inappreciable on the scale. The same principle might even be applied to altitudes up to 6000 feet, as the maximum error would be only 10 feet. For considerable elevations, however, the variations of the temperature between the base and the summit would interfere with the application of the principle.

Nevertheless the best plan is to dispense with altitude scales, whether fixed or movable, and to calculate the heights. Simple rules, giving more reliable results than the attached scales, are at the service of those who need easy processes.

SUMMARY OF RULES AND DIRECTIONS  
FOR USING THE ANEROID IN MEASURING ALTITUDES.

1st. In the absence of a table to aid in computation, but having an Aneroid with the scale of feet, use the formula,

$$D = 55000 \frac{H - h}{H + h}$$

adding  $\frac{1}{500}$  of the estimated altitude for every degree, the *average* temperature is above  $55^\circ$ , and subtracting a like amount when it is below.  $D$ , is the difference of altitude in feet;  $H$  and  $h$  are the readings *in feet* from the Aneroid scale. This gives fair approximations up to 3000 feet.

2d. Having Airy's table, and an Aneroid carefully graduated to inches; take the reading in inches of the barometric scale at both lower and upper stations, also the temperature at both stations. Find from the table the heights in feet corresponding to the barometer readings. Subtract them and correct the remainder

$$\text{by } \frac{T + t' - 100}{1000}$$

The complete formula is

$$D = (H - h) + \left(1 + \frac{T + t' - 100}{1000}\right)$$

$T$  and  $t$  are the observed temperatures;  $H$  and  $h$  are the heights in feet taken from the table.

3d. In the absence of this table, but with a table of logarithms at hand, the barometric heights in inches are to be taken, and the following formula used

$$D = 60000 (\log. B - \log. b) \left(1 + \frac{T + t - 60}{900}\right).$$

$B$  and  $b$  are the barometric readings in inches;  $D$ ,  $T$  and  $t$  as in the other formulas.

To avoid error from the constant changes in barometric pressure, the observations should be simultaneous. This is accomplished in the best manner by using two instruments, and requires,

when the distance between the stations is considerable, two observers. With one instrument only, large errors are avoided by repeating the observation at the first station after taking that at the 2d station, and assuming that any change in barometric pressure that has occurred has been gradual during the absence.

Many Aneroids marked "compensated" exhibit a sensible change when the temperature is varied; such instruments may be serviceable and quite accurate if allowance be made for the error of the instrument. This correction the owner had better determine by experiment. It is easy to subject the Aneroid to such variation of temperature as shall embrace the range at which it is likely to be used, and the movement of the index for each  $10^\circ$  or  $20^\circ$  of temperature recorded.

Aneroids require to be compared from time to time with a good mercurial barometer. While making such comparisons, it is well to remember that the mercurial column and the scale by which it is measured both require correcting, and that during times of rapid changes, in atmospheric pressure, the Aneroid shows such changes more readily than the mercurial barometer.

In measuring heights with the Aneroid care should be taken that the instrument is not influenced by the heat of the hand nor by the direct rays from the sun.

The instrument should always be tapped gently with the finger at the moment of taking an observation.

Considerable care is also required to determine exactly where the index points. It is best accomplished by sighting along the pointer, using one eye only for the purpose.

The following example will illustrate the use of the table.

Barometer at Station A	30.04	Thermometer	$78^\circ$
" " " "	B 28.68	" "	$65^\circ$

From the table we find height corresponding to reading at A is 858 feet. The height for B is 2120 feet.

The approximate height is  $2120 - 858 = 1262$  feet; but the sum of the temperatures is  $143^\circ$ . An additional correction of  $\frac{4.3}{1000}$  is, therefore, to be applied to the above difference; this is 54 feet. The total estimated difference of altitude is then  $1262 + 54 = 1316$  feet.

TABLE FOR ESTIMATING HEIGHTS BY THE ANEROID.

Having read both barometer and thermometer at both stations—Find in the table the altitudes corresponding to the barometric readings. Subtract them and multiply the remainder by

$$1 + \frac{T+t-100}{1000}. \quad T \text{ and } t \text{ being the temperatures.}$$

Barometer Readings.	Heights.	Barometer Readings.	Heights.	Barometer Readings.	Heights.	Barometer Readings.	Heights.
Inches.	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.	Feet.
31.00	00	29.86	1021	28.72	2082	27.58	3186
30.98	18	29.84	1039	28.70	2101	27.56	3206
30.96	35	29.82	1058	28.68	2120	27.54	3225
30.94	53	29.80	1076	28.66	2139	27.52	3245
30.92	71	29.78	1094	28.64	2158	27.50	3265
30.90	88	29.76	1113	28.62	2177	27.48	3285
30.88	106	29.74	1132	28.60	2196	27.46	3305
30.86	124	29.72	1150	28.58	2215	27.44	3325
30.84	142	29.70	1169	28.56	2234	27.42	3345
30.82	160	29.68	1187	28.54	2253	27.40	3365
30.80	177	29.66	1205	28.52	2272	27.38	3384
30.78	195	29.64	1224	28.50	2291	27.36	3404
30.76	212	29.62	1242	28.48	2310	27.34	3424
30.74	230	29.60	1260	28.46	2329	27.32	3444
30.72	247	29.58	1278	28.44	2349	27.30	3464
30.70	265	29.56	1296	28.42	2368	27.28	3484
30.68	283	29.54	1314	28.40	2387	27.26	3504
30.66	301	29.52	1333	28.38	2407	27.24	3524
30.64	318	29.50	1352	28.36	2426	27.22	3544
30.62	336	29.48	1370	28.34	2445	27.20	3564
30.60	354	29.46	1389	28.32	2464	27.18	3584
30.58	372	29.44	1408	28.30	2483	27.16	3604
30.56	390	29.42	1426	28.28	2503	27.14	3624
30.54	407	29.40	1445	28.26	2522	27.12	3644
30.52	425	29.38	1464	28.24	2541	27.10	3665
30.50	443	29.36	1482	28.22	2561	27.08	3685
30.48	461	29.34	1500	28.20	2580	27.06	3705
30.46	479	29.32	1519	28.18	2600	27.04	3725
30.44	497	29.30	1537	28.16	2619	27.02	3745
30.42	515	29.28	1556	28.14	2638	27.00	3765
30.40	533	29.26	1574	28.12	2658	26.98	3785
30.38	551	29.24	1593	28.10	2677	26.96	3806
30.36	569	29.22	1612	28.08	2696	26.94	3826
30.34	587	29.20	1631	28.06	2715	26.92	3846
30.32	605	29.18	1649	28.04	2735	26.90	3866
30.30	622	29.16	1668	28.02	2755	26.88	3886
30.28	640	29.14	1687	28.00	2774	26.86	3907
30.26	658	29.12	1706	27.98	2794	26.84	3927
30.24	676	29.10	1725	27.96	2813	26.82	3948
30.22	694	29.08	1743	27.94	2833	26.80	3968
30.20	712	29.06	1762	27.92	2853	26.78	3988
30.18	730	29.04	1781	27.90	2873	26.76	4009
30.16	749	29.02	1799	27.88	2892	26.74	4030
30.14	767	29.00	1818	27.86	2911	26.72	4050
30.12	785	28.98	1837	27.84	2930	26.70	4070
30.10	803	28.96	1856	27.82	2950	26.68	4091
30.08	821	28.94	1875	27.80	2969	26.66	4111
30.06	839	28.92	1894	27.78	2989	26.64	4132
30.04	857	28.90	1913	27.76	3009	26.62	4152
30.02	875	28.88	1931	27.74	3029	26.60	4172
30.00	893	28.86	1950	27.72	3048	26.58	4192
29.98	911	28.84	1969	27.70	3068	26.56	4212
29.96	929	28.82	1988	27.68	3087	26.54	4233
29.94	947	28.80	2007	27.66	3107	26.52	4254
29.92	965	28.78	2026	27.64	3126	26.50	4274
29.90	983	28.76	2044	27.62	3146	26.48	4294
29.88	1002	28.74	2063	27.60	3166	26.46	4315

Barometer Readings.	Heights.	Barometer Readings.	Heights.	Barometer Readings.	Heights.	Barometer Readings.	Heights.
Inches.	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.	Feet.
26.44	4336	25.12	5733	23.80	7203	22.48	8757
26.42	4357	25.10	5754	23.78	7226	22.46	8781
26.40	4378	25.08	5776	23.76	7249	22.44	8806
26.38	4399	25.06	5798	23.74	7272	22.42	8830
26.36	4419	25.04	5820	23.72	7294	22.40	8855
26.34	4440	25.02	5842	23.70	7316	22.38	8879
26.32	4461	25.00	5863	23.68	7339	22.36	8904
26.30	4482	24.98	5885	23.66	7363	22.34	8928
26.28	4502	24.96	5907	23.64	7386	22.32	8953
26.26	4523	24.94	5929	23.62	7409	22.30	8977
26.24	4544	24.92	5950	23.60	7433	22.28	9002
26.22	4565	24.90	5972	23.58	7456	22.26	9026
26.20	4585	24.88	5994	23.56	7480	22.24	9051
26.18	4606	24.86	6016	23.54	7503	22.22	9075
26.16	4627	24.84	6038	23.52	7527	22.20	9100
26.14	4648	24.82	6060	23.50	7550	22.18	9125
26.12	4669	24.80	6082	23.48	7574	22.16	9150
26.10	4690	24.78	6104	23.46	7597	22.14	9174
26.08	4711	24.76	6126	23.44	7621	22.12	9199
26.06	4731	24.74	6148	23.42	7644	22.10	9224
26.04	4752	24.72	6170	23.40	7667	22.08	9249
26.02	4773	24.70	6192	23.38	7690	22.06	9274
26.00	4794	24.68	6214	23.36	7713	22.04	9298
25.98	4815	24.66	6236	23.34	7736	22.02	9323
25.96	4836	24.64	6258	23.32	7759	22.00	9348
25.94	4857	24.62	6280	23.30	7782	21.98	9372
25.92	4878	24.60	6302	23.28	7805	21.96	9397
25.90	4899	24.58	6324	23.26	7829	21.94	9422
25.88	4920	24.56	6346	23.24	7853	21.92	9447
25.86	4941	24.54	6368	23.22	7876	21.90	9472
25.84	4962	24.52	6390	23.20	7900	21.88	9497
25.82	4983	24.50	6412	23.18	7923	21.86	9522
25.80	5004	24.48	6435	23.16	7946	21.84	9547
25.78	5025	24.46	6458	23.14	7969	21.82	9572
25.76	5046	24.44	6480	23.12	7992	21.80	9597
25.74	5067	24.42	6503	23.10	8015	21.78	9622
25.72	5088	24.40	6525	23.08	8039	21.76	9647
25.70	5110	24.38	6547	23.06	8063	21.74	9672
25.68	5132	24.36	6570	23.04	8086	21.72	9697
25.66	5153	24.34	6592	23.02	8110	21.70	9722
25.64	5174	24.32	6615	23.00	8134	21.68	9747
25.62	5195	24.30	6637	22.98	8158	21.66	9772
25.60	5216	24.28	6659	22.96	8182	21.64	9797
25.58	5237	24.26	6682	22.94	8206	21.62	9822
25.56	5259	24.24	6705	22.92	8230	21.60	9848
25.54	5281	24.22	6727	22.90	8254	21.58	9873
25.52	5302	24.20	6750	22.88	8278	21.56	9898
25.50	5323	24.18	6772	22.86	8302	21.54	9923
25.48	5344	24.16	6795	22.84	8326	21.52	9949
25.46	5365	24.14	6817	22.82	8350	21.50	9974
25.44	5387	24.12	6840	22.80	8374	21.48	9999
25.42	5408	24.10	6862	22.78	8398	21.46	10025
25.40	5429	24.08	6885	22.76	8422	21.44	10050
25.38	5451	24.06	6907	22.74	8446	21.42	10075
25.36	5473	24.04	6930	22.72	8470	21.40	10101
25.34	5495	24.02	6953	22.70	8495	21.38	10126
25.32	5516	24.00	6976	22.68	8519	21.36	10151
25.30	5537	23.98	6999	22.66	8543	21.34	10176
25.28	5559	23.96	7022	22.64	8567	21.32	10202
25.26	5581	23.94	7045	22.62	8591	21.30	10228
25.24	5602	23.92	7068	22.60	8615	21.28	10253
25.22	5624	23.90	7090	22.58	8638	21.26	10278
25.20	5646	23.88	7113	22.56	8661	21.24	10304
25.18	5668	23.86	7135	22.54	8685	21.22	10330
25.16	5689	23.84	7157	22.52	8709	21.20	10355
25.14	5711	23.82	7180	22.50	8733	21.18	10381

Barometer Readings.	Heights.	Barometer Readings.	Heights.	Barometer Readings.	Heights.	Barometer Readings.	Heights.
Inches.	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.	Feet.
21.16	10406	20.86	10798	20.56	11190	20.26	11591
21.14	10432	20.84	10824	20.54	11217	20.24	11618
21.12	10458	20.82	10850	20.52	11243	20.22	11645
21.10	10484	20.80	10876	20.50	11270	20.20	11673
21.08	10509	20.78	10902	20.48	11297	20.18	11700
21.06	10535	20.76	10928	20.46	11324	20.16	11727
21.04	10561	20.74	10954	20.44	11351	20.14	11754
21.02	10587	20.72	10980	20.42	11377	20.12	11781
21.00	10613	20.70	11006	20.40	11404	20.10	11808
20.98	10640	20.68	11032	20.38	11431	20.08	11835
20.96	10667	20.66	11058	20.36	11457	20.06	11863
20.94	10694	20.64	11084	20.34	11483	20.04	11891
20.92	10720	20.62	11110	20.32	11509	20.02	11918
20.90	10746	20.60	11136	20.30	11536	20.00	11945
20.88	10772	20.58	11163	20.28	11563		

The formula directly applied is

$$D = (2120 - 858) \left( 1' + \frac{78 + 65 - 100}{1000} \right) = 1316.26$$

Applying the 3d method we should get, using logarithms

$$\text{Log. } B \ 30.04 = 1.477700$$

$$\text{" } b \ 28.68 = 1.457579$$

$$\text{Log. } B - \text{Log. } b = 0.020121$$

$$D = 60000(0.020121) \left( 1 + \frac{78 + 65 - 60}{900} \right) = 1207.26 \times 1.0083 = 1318 \text{ feet.}$$

The following suggestions to buyers of Aneroids we take from Gen. Ellis's pamphlet :

"If you are not a good judge of the instrument, go to the best maker or seller.

"If you want accuracy prefer a brass case. The back plate of the mechanism being secured to the case, if they are of different metals, as brass and silver, the different rate of expansion by heat sometimes causes error.

"Examine the dial and see if the divisions are *engraved*. If they are *stamped* upon it the instrument is probably worthless for accurate observations. The dial should be electro-plated, and not washed. See that the index is fine and slender, and lies close to the dial. It is best of blued steel. Have no central pointer for showing the position of the index. There should be a small steel pointer attached to the rim, as has been described. See that the dial has the

number of inches you desire. From six to ten inches is a good range for engineering purposes. About three quarters of the circumference can be made to read accurately.

"For a pocket Aneroid buy the largest that can be conveniently carried in the pocket, and not the very smallest size. Two to two and one-fourth inches is a convenient size, and can be made accurate.

"If the dial has a scale of feet, see that it is graduated according to some correct formula, by taking off the numbers corresponding to each inch and comparing them with some known table or formula.

"The instrument should have a case, so that the heat of the hand shall not derange it when observing.

"It is better also to have a thermometer in the dial inside the scale, and dropped lower down, so as not to interfere with the index.

"Instruments that have the zero of the foot scale at thirty inches, particularly those having movable scales are generally erroneously graduated, the same scale being commenced at thirty that should be commenced at thirty-one inches; they are moreover inconvenient to use."

After having reached a depth of 328 feet, M. Godin Lemaire, in boring for coal at La Chapelle, has met with clayey schists, and has therefore abandoned the search.

## THE TRANSMISSION OF POWER TO DISTANCES.

By HENRY ROBINSON, M. Inst. C. E.

Minutes of Proceedings of the Institution of Civil Engineers.

It is proposed in this Paper to record some facts that have come within the Author's experience, or have been communicated to him, respecting the various methods employed to transmit motive power, with a view of considering the circumstances under which one system would be preferable to another. Hitherto the economical production of power in the motor, and its utilization in the appliance to which it is conveyed, have been made the subject of more general and careful investigation than the means of economical transmission.

Water pressure was recognised by Bramah as affording, on account of its incompressibility, a favorable medium for the transmission of force; and it was utilized by him by means of a small pump at a high pressure, acting with the least possible loss by friction on a large piston or ram, thus obviating the necessity for gearing.

The hydraulic system, in its present wide field of application owes its origin, however, to Sir William Armstrong, Vice-President Inst. C.E. (to whom the Author desires to acknowledge indebtedness for his earliest experience in this branch of engineering), who in the year 1846 erected on the Newcastle Quay the first hydraulic crane. This has been followed by the application of water pressure to a variety of purposes with great advantage, especially where the appliances are intermittent in their requirements. The success which has attended the working of the system has suggested its extension to towns, on the co-operative principle, by laying power mains. The first of this kind has recently been carried out by the Author, of which the following is a description. In the year 1872 an Act of Parliament was obtained for the purpose of establishing, at Kingston-upon-Hull, what was termed in the preamble "a system for applying motive power by hydraulic pressure to waterside and land cranes, used for the purpose of raising and landing goods; and for working dock gates and other machinery." The

powers granted under this Act were to be exercised over an area of sixty acres, and they authorized the abstraction from the old harbor of the river Hull (a tributary of the river Humber) an amount of water not exceeding 1,000,000 gallons a day, for distribution within the company's district, for which a payment was to be made to the Corporation of £12 10s per annum for each 250,000 gallons; the water to be used for no other purpose than as a motive power, except with the consent of the Corporation.

A 6-inch pressure main has been laid from the northern boundary of the defined area, near the Cottingham Drain, in a southerly direction along Wincollee, Trippett, Dock Office Row, under the Old Dock Basin (which forms the eastern or river Hull entrance to the Queen's Dock), and crossing this entrance it is laid along the whole length of High Street, terminating close to the western approach of the South Bridge across the river Hull. The length of pressure main, exclusive of the dock crossing, is altogether 1,485 yards, that on the north side of the dock entrance being 673 yards in length, and that on the south side 812 yards. Except at the dock crossing the main consists of cast-iron flanged pipes, of six inches internal diameter, one inch thick, with the usual spigot and faucet, and with gutta-percha ring joints tested to 2,800 pounds per square inch before being laid, and afterwards to 800 pounds per square inch.

Stop-valves at intervals, having a waterway equal to that of the main, divide the main into sections. Air-cocks are fixed on all summits, by which the air is displaced in charging the main. T-pieces for 2-inch, 3-inch, and 4-inch branches are placed at convenient points, from which service-pipes can be carried to the various warehouses, works, &c.

The main was laid across the dock entrance, in a trench dredged to the inverts forming the dock bottom, the solid obstructions met with being removed and the bottom levelled by a diver.

The pipes across the dock are of six inches internal diameter, made of welded wrought iron  $\frac{3}{4}$  inch thick, bent to template to suit the curves of the sides and bottom of the dock, and were tested to 3,000 pounds per inch at the manufacturer's. They were put together at the side of the dock, and tested to  $\frac{1}{2}$  ton to the inch before being lowered into the trench. This was done from barges, and when the pipes were in position they were well concreted, to protect them from being injured by anchors or by weights falling overboard from ships. This part of the work has been tested in an unexpected way by the stranding of a large ship over the pipes, which, however, were in no way injured.

The power to supply the water pressure is concentrated at one pumping station in Machell Street, where an engine-house has been built to receive four sixty horse-power engines. The ground being silty and bad, the foundations were carried down to the hard clay, a depth of twenty-four feet, the walls being built on arches resting on concrete piers. The engine-house is covered by a tank fitted with filtering boxes, through which the water pumped from the river Hull passes before it is delivered to the engines. Two pairs of high-pressure horizontal pumping engines have been erected, each engine being of sixty horse-power, and capable of pumping 130 gallons per minute at 700 pounds pressure per square inch, with steam at 100 pounds pressure. The steam cylinders are  $12\frac{1}{4}$  inches in diameter and the length of stroke 24 inches; the force pumps, which are double-acting, have a  $4\frac{9}{16}$ -inch piston, the piston rod being  $3\frac{1}{8}$  inch in diameter. Space is provided in the engine-house for two additional pairs of sixty horse-power engines, which can be erected at a future time when the demand for the water pressure requires further engine power. Two Lancashire boilers, twenty-two feet six inches long and six feet six inches in diameter, supply steam to the engines.

An Appold centrifugal pump (in duplicate), fixed in the engine-house, draws the water from the river Hull, a distance of 125 yards, through a 10-inch pipe, and delivers it into the tank, the lift being thirty-five feet from low tide.

The pump has an 8-inch suction, and is driven by a Brotherhood's 4-inch three-cylinder engine, also in duplicate. Each engine and pump supply 800 gallons of water per minute, with 100 pounds steam pressure. A 6-inch return pipe is laid from the tank to the river, serving both as an overflow pipe and as a means of cleaning out the tank.

In connection with the hydraulic system, the "accumulator" fulfills an important office, and may be described as an apparatus to accumulate at a constant pressure, which is obtained by a load, the power given out by a steam engine. A cast-iron cylinder has a ram working in it, from the top of which a weighted case is suspended by a crosshead. The weight in the case is adjusted to give the desired pressure on the column of water pumped by the engine into the cylinder of the accumulator, from which it is conveyed through the main to the points of consumption. The accumulator, besides serving to produce an artificial head, also stores up the water pumped when it is in excess of the water consumed; and, in fact, performs in the hydraulic system the functions of the fly-wheel of a steam engine. As the consumption of water by the machines connected with the main falls below the supply of water pumped by the engine, the ram rises and stores in the cylinder the excess, until the ram has risen to the top of its stroke, when it cuts off the steam from the engine by closing the throttle valve. On the other hand, when the consumption of water by the machines is greater than is being supplied at the time by the engine, the ram falls and supplies the deficiency, at the same time opening the steam throttle valve by which the full power of the engine is brought into operation. The accumulator thus acts both as a reservoir of power and as a conservator of its distribution.

One accumulator is erected at the pumping station in Machell Street. It has a diameter of eighteen inches, and a stroke of twenty feet. The case is loaded with  $57\frac{1}{2}$  tons of copper slag and sand, which produce a pressure of 610 pounds per inch in the main. Provision is made for an additional accumulator at the pumping station when required. Another accumulator will be placed at

Grimsby Lane, towards the southern extremity of the line of main.

Several observations were made to ascertain the useful effect of the engines and accumulator, and the mean was found to be seventy-six per cent., five per cent being the loss in the pumps.

The outlay has been £17,000.

In carrying out these works, the Author received every assistance from the Hull Dock Company, and their Engineer, Mr. Marillier, M. Inst. C.E.; from the Corporation of Hull and their Engineer, Mr. J. Fox Sharpe, M. Inst. C.E., and from Mr. Thornton, who acted as Resident Engineer. The pipes were supplied by the Staveley Coal and Iron Company; the machinery by the Hydraulic Engineering Company.

The Dock Company has taken a 4-inch branch off the power main to work cranes and appliances on the south side of the Queen's Dock, for which it pays 4s. per 1,000 gallons of water, with a minimum charge of £200 per annum for the first fifteen connections, and a further charge of £15 per annum for each connection above that number.

The following tariff has been issued by the Company of the rates at which it is proposed to supply the water power:

	£.
" 1 crane in one warehouse...	52 per annum.
2 cranes " " " ...	94 "
3 " " " " ...	132 "
4 " " " " ...	166 "

"Each crane will have a counter attached to it to register the amount of work done. One hundred tons may be lifted 40 feet or 200 tons 20 feet, and so on each day by each crane for the above charge, which is under  $\frac{1}{2}$ d per ton for a lift of 40 feet. If more work than this is done, the extra work will be charged at the rate of 4s. for every additional 100 tons lifted 40 feet. Special rates will be made for working presses, hydraulic engines, capstans, small cranes, &c., as occasion arises."

The numerous purposes to which hydraulic power is applied may be briefly referred to. It is employed in docks in working cranes, jiggers, hoists, in opening dock gates and sluices, and for capstans to haul ships. Cranes capable of traveling along the side of the dock, so that they can be adjusted to suit the holds of

ships, are preferred to fixed cranes, the power being taken off the main by hydrants connected with the crane by pipes having union joints. In railway yards it is applied to capstans for hauling wagons and making up goods trains, saving both space and horse power; also to wagon hoists, swing and draw bridges, traversing machines, &c. It is employed to work shop tools, flanging presses, riveting machines (the rivets being closed by a squeeze instead of by the blow of a hammer), also to forging iron by passing it at a welding heat, into the desired shapes in moulds, resulting both in a saving of material and subsequent shaping, and in causing the fibre of the iron to follow the form of the object produced to an extent not possible under the hammer. In the moulding shops of a foundry, hydraulic power is found preferable to the ordinary gearing, owing to the absence of vibration in its working. It is used on board ship to work the steering gear, to raise the anchor, and to lift and discharge goods. The 100-ton gun recently made at Elswick for the Italian Government has hydraulic apparatus applied to it, by which the recoil is taken up in less than 46 inches. A special crane to lift this gun at Spezia has been arranged, the novel feature of which consists in the cylinder being suspended from the jib-head which, acting directly with the load, enables the lowering of the gun to be regulated by the escape of the water from the cylinder.

Where the ordinary pressure of about 700 pounds to the inch is insufficient to work shop tools or presses, it can be increased by the intervention of an intensifier, which is a machine having two cylinders in line with each other. In the one the pressure of 700 pounds is received on a piston of large area, acting directly on a ram of lesser area in the second cylinder. The areas of the piston and ram can be proportioned to increase the pressure to any required degree.

In cold climates the pipes and machines are, as a rule, placed either underground or in buildings. Where the parts are unavoidably exposed the usual precaution adopted is either to run out the water when the machines are not working, or to keep a gas jet burning near them. Where water is scarce, a return pipe conveys the waste water from the

machines back to the engines for use over again.

The advantages that will accrue from the introduction of a main to distribute power, by means of water pressure, are considered to be as follows:

The consumer will effect a great reduction of expense where he is using hand power; and where steam power is employed, the engines, boilers, and the skilled labor required to attend to them can be dispensed with, the space saved being made available for other purposes; while at the same time the risk of fire is removed. In Hull the substitution in warehouses of hydraulic power for steam power will cause a reduction in the rates of insurance of 1s. per cent. per annum, which would represent a considerable saving in the numerous warehouses storing grain, seed, &c., disastrous fires in them being of frequent occurrence. In the bonded warehouses of docks, steam power is not, as a rule, permitted; but where steam cranes are employed it involves considerable increase in the fire risk to those warehousing in the buildings served by them.

Great acceleration of business will be produced compared with hand power, as goods, whether from ships or wagons, can be discharged with increased rapidity, hydraulic cranes lifting, from 6 to 10 feet a second, an average of about 1,000 foot-tons per hour. The number of men on the premises can be reduced, hydraulic appliances being worked by a few unskilled laborers. The upper floors of warehouses can be more utilized, and higher floors can be advantageously added to existing buildings. The power will be always and instantly available to meet the requirements of the consumer and at a cost to him only in proportion to the power absolutely consumed. The system can also be utilized to extinguish fires, by pumping against a loaded valve and air-vessel at about 100 pounds to the inch. At the St. Katharine Docks a complete system of this kind has been carried out, and has, in several instances enabled fires to be promptly overcome.

The pressure in Water Companies' mains has been used to work lifts and other machines. The cost, however, of pure water, added to its low pressure, prevents its being employed except to a limited extent.

Before leaving the subject of the distribution of power by water mains charged at a high pressure, it may be interesting to quote the following opinion of the late Sir W. Fairbairn, Bart., M. Inst. C.E., with whom the Author and Mr. J. S. Wilkinson, M. Inst. C.E., were in communication, in the year 1867, as to the application of the hydraulic system by means of power mains in Manchester. "Your proposal to erect steam engines and lay down pipes for the purpose of working accumulators for supplying hydraulic power in different localities of the city of Manchester seems to have several advantages over the system now in use in the different warehouses where steam is employed. In the first place, it would remove steam engines and boilers from the premises, lessen the risk from fire and boiler explosions; and, secondly, it would supply the necessary power to work cranes, hoists, hydraulic presses, &c., in these depots on principles of increased security."

In the transmission of power by water at a high pressure, the loss due to friction in the main is but trifling, compared with the total pressure, when the main is well proportioned with reference to the position and amount of power required to be consumed, and when accumulators are placed at proper intervals to maintain the pressure. Where the original smoothness of the pipe is destroyed, by deposits taking place on its inner surface, an increase in the skin friction will result, together with a diminution in the size of the pipe. As the loss of head varies inversely as the fifth power of the diameter, the loss will from this cause in time become appreciable. In the case of the 6-inch main at Hull, the loss of pressure due to friction at a point 1,500 yards from the engine, would be about five pounds per inch, with one pair of engines working at its maximum speed, delivering 130 gallons of water at 700 pounds pressure per minute, or four times that loss if both engines were working delivering twice that amount of water. The erection of a second accumulator at the end of the main, remote from the engine, as intended, will practically place that part of the main in the same position as to pressure as the main near the engines. This arises from the fact that the water

pressure being withdrawn from the main in an intermittent manner, the intervals between the periods of water abstraction, however short, enable the continuity of pressure between the engine and the distant accumulator to be maintained, and the effect of the loss of head due to friction to be practically compensated for. At a point midway between the engine and the second accumulator, it can only reach  $1\frac{1}{4}$  pounds and 5 pounds per inch, or about  $\frac{1}{4}$  and 1 per cent. as maxima, when one or both engines are at work.

Gauges have been placed on a main composed of 4-inch, 3-inch, and 2-inch pipes, in the Great Western railway yard at Paddington, at points from 1,000 to 1,600 yards apart, and the pressure has been found to be practically the same during the working of the machines in the usual way. At Swansea, wherever the pressure in the main has been tried, it has been found to be uniform; close to the accumulators it is greater, and at the accumulators themselves the pressure has been raised to 900 pounds by keeping the engine going.

Contractions in the main, either through the waterway of the valves being less than that of the pipes, or through a reduction in the size of the pipes, give rise to fluctuations of pressure at variance with the uniformity attainable when the main is properly proportioned. These fluctuations are explained by the fact that, where a fluid passes from a large to a smaller pipe, a diminution of pressure takes place corresponding with the diminution of sectional area. The converse applies to the case of the passage of a fluid from a small to a larger pipe. The fluid, on entering the larger pipe, travels at a diminished velocity, which implies the existence of a greater pressure in front than behind it. Water passing from a small pipe through a large one, and then to a similar sized small pipe, will return to its original pressure after the interval of increased pressure, provided there are well-tapered junctions at the points of change. It follows, then, that changes in the sizes of the main result in changes of velocity, and therefore of pressure, by Bernoulli's law that the pressures vary with the differences of the squares of the velocities. Disregarding friction,

the pressure in a main of uniform size will be constant if the water pumped into it is sufficient to replace that withdrawn; in other words, where the velocity is constant, but where contraction takes place, a diminution of pressure will be experienced throughout the contracted length unless an accumulator is placed there—in which case it practically remedies the inequality of pressure by preserving the uniformity of flow.

This subject has been considered with respect to ship resistance by Mr. Froude, M. Inst. C.E.

Water power may, therefore, be regarded as capable of transmission with but trifling loss. In the machines themselves, the useful effect is as high as ninety per cent. in direct-acting apparatus, and as low as fifty per cent. in cranes with great multiplying power.

Mr. Percy Westmacott, M. Inst. C.E., has enabled the Author to give some information respecting the practice at Elswick, where the co-efficients of effect obtained in hydraulic machines of ordinary make are taken as follows:

Direct-acting.....	93 per cent.
2 to 1.....	80 "
4 " 1.....	76 "
6 " 1.....	72 "
8 " 1.....	67 "
10 " 1.....	63 "
12 " 1.....	59 "
14 " 1.....	54 "
16 " 1.....	50 "

These co-efficients are based on ordinary hemp packing (well-made cupped leathers increase the efficiency), and with sheaves and wrought-iron pins, there being no exceptional arrangements for lubrication. Where, however, special precautions have been taken, such as in the traversing machines which were at work some years ago at St. Pancras goods station, where a large diameter of sheave, and a small diameter of hard steel pin were employed together with careful fitting of parts, the efficiency multiplying 20 to 1 was as high as 66 per cent. This machine had a travel of 200 feet with a load of  $17\frac{1}{4}$  tons.

It is considered that the co-efficient of effect obtained from a steam engine pumping into an accumulator may be taken at 81.7 per cent, the amount lost by friction in the accumulator gland being 8.3 per cent. It is found by experi-

ment that the difference of pressure with the accumulator at 700 pounds rising or falling is about 30 pounds, representing 2.14 per cent of effect. The compounded efficiency will, therefore, be ascertained by combining the efficiency of the engine, which has been shown to be 76 per cent. at Hull, with the above varying rates of efficiency.

In 1865, Mr. Hawthorn, in his Paper on Docks and Warehouses at Marseilles, gave, as the result of some experiments, the compounded effect as 30, 45, and 60 per cent. In explanation of these admittedly low results, it was shown that the machines on which the experiments were made were all new; and further, that the water, after being used, was forced back through a considerable length of piping to a cistern over the engine-house. In 1862, Mr. Abernethy, Vice-President Inst. C.E., in a Paper on the Port of Swansea, made a deduction of 20 per cent. from the water delivered by the engines to work the hydraulic machinery as an allowance for friction and leakage.

Hydraulic appliances cause a waste of water when the maximum capabilities of the machine are not exerted. In the case of a hoist to raise a loaded goods wagon, the hoist may occasionally be used to lift only an empty wagon, when as much water is consumed as would be required to lift the loaded one. It must, however, be remembered that no power is being consumed in any way during the intervals between the operations, and the conservation of power in these intervals may be considered as compensating for the occasional wasteful consumption at the moments of its employment. The load to be lifted by cranes can be adjusted by an arrangement of valves so that the amount of water used is regulated to single or double power. If this adjustment could be carried further, it would enable the variations in the work to be still better equalized, and would lessen the objection to water not admitting of being worked expansively.

In the Albert Dock of the Hull Dock Company a sixty horse-power engine supplies water for working an 80-feet swing-bridge, nineteen hydraulic engines working gates, sluices, and capstans, three 20-ton coal hoists, one 15-ton crane, one three-ton crane, and thirty-

four  $1\frac{1}{2}$ -ton cranes. By permission of Mr. Marillier, the Engineer of the Company, the following data have been obtained. These machines are worked at a pressure of 775 pounds per inch, through 5,350 feet of 5-inch pipe, 1,400 feet of 4-inch pipe, with 3-inch and 2-inch branches to the dock gates and warehouses. The cost of supplying water power for the year 1875 was £1,367 3s. 1d., which gives, after taking 80 per cent. as the useful effect of the water after delivery into the main:

	d.		
Engine power.....	0.24	per 100 foot-tons	
15 per cent. for interest	}	0.88	“ “
on capital and depreciation.....			
		1.12	“ “
Add for repairs.....		0.13	“ “
		1.25	“ “

At Cotton's Wharf, London, there are ten 25-cwt. hydraulic cranes lifting 40 feet, four 2-ton single-power cranes, one 4.2-ton double-power crane and one 48-ton press worked at a pressure of 700 pounds per inch; the cost when only six cranes were in operation, which is the average number, was

	d.		
Engine power.....	0.63	per 100 foot-tons.	
15 per cent. for interest	}	1.26	“ “
and depreciation....			
		1.89	

The cost of labor at the cranes was 0.46d. per 100 foot-tons. If the whole of the sixteen appliances were working, the cost would be

	d.		
Engine power.....	0.23	per 100 foot-tons.	
15 per cent. for interest	}	0.47	“ “
and depreciation....			
		0.70	“ “

The labor at the cranes being the same as before, namely, 0.46d. per 100 foot-tons.

At the St. Katharine Docks, engines of 140 horse-power, nominal, pump 5,000,000 cubic feet of water annually at 600 pounds pressure through 1,200 yards of 7-inch main, supplying power to work a swing-bridge and upwards of seventy-five cranes, hoists, and presses. The power exerted annually is nearly 193,000,000 foot-tons, or, taking 80 per cent. efficiency, more than 154,000,000 foot-tons.

The cost of the engines, boilers, accumulators, pipes, and appliances. = £35,000  
 Foundations of engines and boiler house. .... = £12,000

The cost of water delivered into the main, including coal, wages, repairs and supervision, is 10s. per 1,000 cubic feet. The cost of the water power is therefore as follows:

Engine power.....	d.	
15 per cent. for interest on capital and depreciation. }	= 0.39 per 100 foot-tons.	
	= 1.10 “ “	
	<u>1.49 “ “</u>	

At the London Docks, engines of 185 nominal horse-power pump 7,000,000 cubic feet of water per annum, of which 4,250,000 cubic feet are pumped at 750 pounds pressure through 1,450 yards of 5-inch pipe, 640 yards of 4-inch, and terminating with 550 yards of 3-inch. The remaining 2,750,000 cubic feet are pumped at 650 pounds pressure through 750 yards of 6-inch pipe. These jointly work the swing-bridges, lock-gates, and upwards of eighty cranes, hoists, presses, &c.

The cost of water delivered into the main, including coals, wages, repairs, and supervision, is 10s. per 1,000 cubic feet. The cost of the power will therefore be as follows:

Engine power.....	d.	
15 per cent. for interest and depreciation. }	0.33 per 100 foot-tons.	
	0.88 “ “	
	<u>1.21</u>	

At the Victoria Docks, engines of 280 nominal horse-power pump 8,000,000 cubic feet per annum at 780 pounds pressure through 700 yards of 5-inch pipe, 2,000 yards of 4-inch, terminating with 200 yards of 3-inch pipe. The power exerted is 401,000,000 foot-tons, or 321,000,000 foot-tons at 80 per cent. efficiency; and this power is applied to working a swing-bridge, lock gates, capstans, and upwards of one hundred cranes and hoists.

The cost of water delivered into the main, including coals, wages, repairs, and supervision, is 10s. per 1,000 cubic feet. The cost of the power will therefore be as follows:

Engine power.....	d.	
15 per cent. for interest and depreciation. }	0.33 per 100 foot-tons.	
	0.88 “ “	
	<u>1.18 “ “</u>	

At the Great Western railway station at Paddington, a seventy horse-power engine supplies water at 700 pounds per square inch to two wagon hoists, three hauling machines, twenty turntables, fifty-four 25-cwt. cranes, sixteen hoists, three capstan engines, three traversing tables, two draw-bridges, one ticket-printing machine, and four dropping platforms. According to Mr. H. Kirtley, the average consumption of water is 25,600,000 gallons per annum, obtained from the Water Company at 4d. per 1,000 gallons, one-fourth being returned and three-fourths run to waste. The cost of supplying this appears to be 1.10d. per 100 foot-tons, taking 80 per cent. efficiency of water delivered, and allowing 15 per cent. for interest and depreciation, or adding 0.13d. per 100 foot-tons for repairs = 1.23d. per 100 foot-tons.

At the Swansea Docks, the amount of water pumped in the year ending Midsummer 1876 was 20,750,000 gallons, at 700 pounds per inch, and the working expenses were:

	£.	s.	d.
Coal and fuel.....	1,056	19	9
Stores.....	134	15	5
Wages.....	699	14	1
	<u>1,891</u>	<u>9</u>	<u>3</u>
Wages and repairs.....	412	6	10
Materials.....	244	7	6
	<u>£656</u>	<u>14</u>	<u>4</u>

The cost will therefore be, taking 80 per cent. for the useful effect of the water delivered into the main:—

Engine power.....	d.	
15% (on £22,000) for interest and depreciation..... }	0.38 per 100 foot-tons.	
	0.66 “ “	
	<u>1.04 “ “</u>	

The extra cost for wages, repairs, and materials would be 0.13d. per 100 foot-tons, making the total cost 1.17d. per 100 foot-tons.

The following is a summary of the foregoing data, and represents the cost of water power at pressures varying from 600 to 780 pounds per square inch, taking 80 per cent. as the efficiency of the water pressure after delivery into the main, and allowing 15 per cent. for interest and depreciation.

	d.		
Albert Docks, Hull....	1.25	per 100 foot-tons.	
Cotton's Wharf (maximum).....	1.89	"	"
Cotton's Wharf (minimum).....	0.70	"	"
Paddington.....	1.23	"	"
Swansea.....	1.17	"	"
St. Katharine Docks...	1.49	"	"
London Docks.....	1.21	"	"
Victoria Docks.....	1.18	"	"
Mean.....	1.26	"	"

Herr Pfaehler has given particulars of the employment of water at the Sulzbach Altenwald colliery, near Saarbrücken, to transmit the power from a steam engine at the surface to work pumps at the bottom of a shaft 306 yards deep. The steam engine has a cylinder 53 inches in diameter and 61.5 inches stroke, connected with pressure plunges 9 inches in diameter and the same stroke, and these plungers are brought into connection with an under ground pumping engine, consisting of four pressure pumps, with plungers 6 inches in diameter and 66 inches stroke, arranged in pairs, and put in motion alternately by the surface plungers. Between each pair of plungers, which are connected by a crosshead, is placed the working plunger of one of the mine pumps. The engine at the surface transmits the effort of each plunger through its rod tube to the corresponding pair of pressure pumps underground and this actuates the working plunger connected with it, either drawing or forcing water, the other pairs acting conversely. The water is forced into an air-vessel, and thence through the rising main in one lift to the surface, the power supplied by the descent of water in one column being nearly sufficient to effect its return in the other. The tubes were proved to 100 atmospheres; the working pressure on the underground pumps, due to the difference between their areas and those of the pumps at the surface, is 50 atmospheres, and the hydrostatic head in the rods being 27 atmospheres, the total working pressure, including friction, is 77 atmospheres, or about 1,155 pounds per inch. The engine is worked at a speed of 10 double strokes per minute when the discharge is permanent and continuous. Careful observations were made to ascertain the work absorbed by the friction of the different parts of the machinery, and it was found to be from

25 to 29 per cent. of the total power developed. The effective work of the pumps at 10 double strokes per minute was 100 HP., and the indicated HP. of the engine, with a mean pressure of 20 pounds per square inch on the piston, was 136 HP., which gives the combined duty = 0.73 of the total power expended.

In the lead mines at Allenheads, in Northumberland, the power for working the machines is derived by water wheels from a natural fall of water at a considerable distance from the points of application, the power being transmitted through pipes charged to a high pressure by accumulators.

The power derived from natural falls of water in mining regions is frequently transmitted by draw rods connected with a crank, exerting a direct pull against a weight during half its revolution, thus storing up power for the return stroke, the rods being in tension throughout. Although this is a simple method of conveying power to considerable distances, it is not an economical means of producing rotary motion.

The other chief methods of transmitting power are steam, compressed air, shafting, and ropes.

In conveying steam to a great distance loss of power occurs through condensation, although, where the pipes are properly proportioned and protected, no appreciable loss has been found in the pressure at a distance of 1,000 feet from the boiler. For any extensive system of transmitting power steam is under disadvantages, as, besides the liability to condensation, there is the difficulty of keeping good joints, owing to expansion and contraction, and the fluctuations of pressure where the main is tapped at many points. In working appliances intermittently by steam, the parts get cold whilst they are not in use, and on the admission of steam condensation takes place, resulting both in loss of power and liability to breakage from starting with water in the cylinder.

On the 25th of May, 1841, a Paper was read at this Institution by the late Mr. John Grantham, M. Inst. C.E., on the working of the Lime Street tunnel on the Liverpool and Manchester railway. This was completed in 1836, and was worked by two pairs of stationary

non-condensing engines supplied with steam from boilers situated (in compliance with the provisions of an Act of Parliament) at the mouths of the Crown Street and Wapping tunnels, a distance of 448 yards, the steam being conveyed in 10-inch pipes laid in a tunnel cut in the solid rock. The length of the incline was 2,370 yards, 2,220 yards being in tunnel having a mean gradient of 1 in 92. The average weight of the trains drawn up was 55 tons, and the time occupied was six minutes. The engines were side-lever, having cylinders 25 inches in diameter and 6 feet stroke, working a drum 21 feet in diameter, making usually twenty-two revolutions per minute, drawing a train up the incline at the rate of 15 miles per hour. The pressure of steam was generally from 50 to 60 lbs. when the engines began to wind, and fell gradually to 30 lbs. From experiments made at the time, Mr. Edward Woods, M. Inst. C.E., found that each pound per square inch pressure of steam upon the pistons, above 7.56 lbs. required to overcome friction, was capable of drawing one carriage weighing 5 tons up the incline. Also that when the engine was standing still the difference of pressure between the boiler and the steam reservoir was about 3 lbs., and when working 13 lbs. The quantity of steam condensed was on an average 156 gallons per hour, and this was collected in a small receiver in the engine-room, the pipes being laid with a fall in that direction. Eventually boilers were placed close to the engines, and the transmission of steam from the old boilers was discontinued.

A steam crane of Messrs. Appleby has been at work at Harwich since 1865, and particulars were obtained of the cost of working for six months. The weight lifted was 18,375 tons, or 118 tons a day raised an average height of 20 feet, and the cost was as follows :

Labor, fuel, oil, waste, &c. ....	d.	
15 per cent. on £500 (the cost of crane) for interest on capital and depreciation	3.98	per 100 foot-tons.
	2.45	" "
	6.43	" "

This includes the cost of labor at the crane, which, if taken at 0.46d. per 100 foot-tons, reduces the cost to 5.99d. per

100 foot-tons. This crane, however, was not working continuously, and it was stated to be capable of performing three times that duty. If so, the cost would be reduced to about 2½d. per 100 foot-tons, or deducting the labor at the crane, to 2.03d. per 100 foot-tons.

Some direct-acting hoists made by the same firm lift 6 cwt. to a height of 40 feet in seven seconds, the steam pressure being 50 pounds per square inch, and the consumption of steam 14 cubic feet. The time required to lift and lower a bale weighing 12 cwt is twelve seconds, and the consumption of steam is 27 cubic feet. The apparent discrepancy between these two results is accounted for by the fact, that, in lowering, the steam is used only as a brake, so that the consumption is but little in excess of what would be required to lift the weight to the height above indicated.

Mr. Maxwell (under whose superintendence the improvements to the river Medlock were carried out in 1869-70) states that a steam crane lifted 563 tons of excavated material to a height of 33 feet, and discharged it into carts in ten hours. The cost of the crane was £300. The fuel came to 2s. 2d. and the labor to 4s. 6d. a day. The cost was therefore:

Engine power. ....	d.	0.43	per 100 foot-tons.
15 per cent. on capital for interest and depreciation. ....	0.18	"	"
	0.61	"	"

The labor at the crane came to 2s. a day, or 1.3d. per 100 foot-tons. These conditions may be regarded as exceptionally favorable.

A 6-ton steam crane at the Llanelly Dock raised 10,321 tons an average height of 27 feet in nine months at a cost of £87 19s. 6d. The cost was therefore :

Working expenses. ....	d.	7.57	per 100 foot-tons.
15% on capital £478 (cost of crane) for interest and depreciation. ....	4.63	"	"
	12.20	"	"

The crane, however, was not working to its full capabilities, and may be regarded as an unfavorable example.

Compressed air is largely employed to transmit power, especially for under-

ground operations, where the conditions are more favorable to its employment than either steam or water pressure. Considerable loss of power arises in the operation of compression, when, as the temperature increases with the density, cooling is necessary, and the heat thus abstracted represents power lost. In performing work by expansion the temperature of the air falls, the work done being in proportion to the heat that has disappeared during expansion, therefore the less the degree of compression the greater the efficiency. For pressures of from 1 to 10 atmospheres, M. Paul Piccard states that the efficiency, when the air is not worked expansively but is admitted for the whole of the stroke, varies from 100 to 39.1, and that taken into account the efficiency of the machines themselves at 70 per cent., the compounded efficiency is about 50 per cent., although, in practice it rarely exceeds 30 per cent.

The late Professor Rankine states that the loss of power seldom amounted to less than from 65 to 75 per cent. of the whole power of the compressing engine, and that the loss in transmission through well-proportioned pipes was about 10 per cent. per mile. Dr. Siemens has stated that his investigations led him to the conclusion that the attainable limit of the useful effect of compressed air was about 50 per cent. of the power exerted in compression.

In collieries under the charge of Mr. Thomas W. Jeffcock, near Sheffield, compressed air is employed in hauling coal on levels and inclines, and for pumping up an incline plane underground. The air is taken down to the bottom of shafts 320 and 350 yards deep respectively, and conveyed to distances of 630 and 1,614 yards. In the first case the safety-valve on the surface is set to blow off at 48 lbs. to the inch, and when this is blowing off, the gauge in the workings, at 630 yards from the pit bottom, registers 50 lbs., showing a gain of 2 lbs. This was observed whilst the engine was employed in pumping water and hauling coal. In the second case the pressure of 30 lbs. at the surface is also increased 2 or 3 lbs., at 1,614 yards from the pit bottom; when at 45 lbs. at the surface it is 47 lbs. underground, and when at 60 lbs. at the surface it is

63 lbs. underground. The tests in the second case were made when the engine was pumping water and running at a regular speed. At another place the air is conveyed nearly 2,000 yards. In these cases it is found there is a loss of 50 per cent. between the boilers and the air receiver at the surface.

At Ryhope Colliery in Durham, Mr. W. F. Hall uses compressed air for underground haulage, and enables the Author to give the following data:—The air is compressed at the surface by an engine having two steam cylinders, 32 inches in diameter, working direct two air-cylinders, 33 inches in diameter, and having 5 feet stroke. The air is forced into a first receiver on the surface, which is 30 feet long by 6 feet in diameter, and from there it is conducted down the pit, 518 yards deep, in 9-inch malleable iron pipes  $\frac{3}{8}$  inch thick, to a second receiver 12 feet long and 4 feet in diameter, and adjusted to blow off at 50 lbs. pressure. The air is taken from the second to a third receiver, distant 101 yards, in 8-inch pipes, and 861 yards farther to a fourth receiver, and thence to the first hauling engine. The distance from the receiver on the surface to the first hauling engine below is 1,505 yards. This engine has a double 14-inch cylinder of 22 inches stroke, and the rope-drum, which is 4 feet in diameter, works through 3 to 1 spur gear. It hauls thirty-six 1-ton tubs up the first engine plane in ten minutes when full, and in seven minutes when empty. In some parts of this incline the gradient is about 1 in 10 against the load, and is a steeper plane than the one next referred to. A second engine, of the same size, but geared  $2\frac{1}{2}$  to 1, is supplied with air from the receiver at the bottom of the pit, by a 6-inch pipe having two receivers on it. This engine, which is 1,308 yards from the receiver on the surface, hauls thirty-eight 1-ton tubs a distance of 2,200 yards up 1 in 18 and 2 in 18 in six minutes when full, and in five minutes when empty. A third double engine, having 10-inch cylinders, works a rope-drum 3 feet 6 inches in diameter through 5 to 1 gearing. This hauls thirty-six 1-ton tubs 750 yards in four minutes with full sets, and in three minutes when empty. Particulars of the temperature and pressure of the air at this

TABLE 1.—EXPERIMENTS WITH COMPRESSED AIR MADE AT RYHOPE COLLIERY, DURHAM, FOR WORKING AN UNDERGROUND HAULING ENGINE.

Time of Measurements.	Number of Strokes of Steam Engine at Bank.	Bank Steam Pressure.	Bank Air Pressure.	Temperature of Air at Outlet.	Temperature of Air in the Outlet Pipe 6 ft. 10 ins. from the Cylinders.	Temperature of Air at No. 1 Receiver, bottom of Pit.	Pressure of Air at No. 1 Receiver.	Temperature of Air in No. 2 Receiver, top of the Engine Bank.	Temperature of Air at Engine in bye Receivers.	Pressure of Air at Engine.	Remarks.
H. M.		lbs.	lbs.				lbs.			lbs.	
10 15	14	15	40	216	236	75	46	66	58	45	Engine standing.
10 20	14	15	41	214	234	75	46	66	58	39	Engine running
10 25	14	16	39	216	236	74	44	66	58	40½	empty sett in-
10 30	16	17	42	216	236	74	46	66	58	41½	bye.
10 35	14	17	33	208	228	75	47	66	58	35	Engine running
10 40	14	18	34	206	226	74	35	66	58	30	full sett out-
											bye from No. 4
											landing.

colliery under varying circumstances, are given in Table I.

The cost of working has been ascertained to be as follows:

	Per day.
Wages, stores, and coals for engines, boilers, and compressors at surface.....	5 13 10
Wages of engine-men and rope-winders, and stores for underground haulage.....	3 4 4
	£8 18 2

The average number of tons raised is 2,200 per day. The cost of working is therefore 0.97d. per ton. This is exclusive of the ropes, which, if allowed for, would raise the cost of haulage to about 1½d. per ton.

Compressed air is used at the Gartsherrie works of Messrs. Bairds for coal-cutting machines, and to a small extent for under-ground haulage. It is worked at a pressure of from 30 to 50 pounds per square inch; 2½ cubic feet of steam at 40 pounds pressure are found to give 1 cubic foot of air at 50 pounds, which makes the useful effect of compressed air about 50 per cent. that of steam. The compressed air has been conveyed 800 yards in ordinary cast-iron flanged pipes, faced and bolted with india-rubber joints, with but little loss by transmission. It is considered that about eighty per cent. of the power is wasted through loss of heat and friction.

Compressed air has also been exten-

sively employed at the Powell Duffryn collieries, particulars of which Mr. Daniel, of Leeds, gave at the Cardiff meeting of the Institution of Mechanical Engineers. In these collieries it was intended to dispense with all horse-power underground, portable hauling engines being substituted for ponies and boys to bring the coal from the working faces to the branch roads. The pressure at which the air is worked is forty pounds per square inch, and experiments were made to ascertain the useful effect with steam at 28 pounds pressure through nearly ¾ of the stroke, and it was found to be only 25.8 per cent. with air at 40 pounds pressure, and 45.8 per cent. with air at 19 pounds pressure. If the steam pressure had been 70 pounds, and cut off at ¼ stroke, better results would have been obtained, and the useful effect at 40 pounds raised from 25 to 50 per cent., which is in agreement with results elsewhere.

French engineers have given considerable attention to the employment of compressed air for locomotive purposes, and an engine on this principle, designed by M. Mékarski, has been tried on the Courbevoie tramway at Paris. Particulars of this are given in the "Portefeuille Economique des Machines," and also in "Engineering" for August 18, 1876. The air is stored at a pressure of twenty-five atmospheres in thirteen charcoal-iron

cylindrical reservoirs, under the floor of the tram-car, and is passed through a vessel containing hot water, which increases its elasticity, and thence through a reducing valve, where the pressure is controlled by a hand wheel, to the cylinder where it is utilised. This tram-car is stated to have run  $4\frac{1}{2}$  miles with forty-five people on it without being recharged. Experiments with similar objects are now being made at Woolwich Arsenal by Major Beaumont, R.E., M.P. He has arranged a compressed-air locomotive, consisting of about seventy steel cylinders four inches in diameter and six feet long, containing air at a high pressure. These are piled together in an oblique stack, and supply sufficient air to draw light loads a considerable distance. Mr. Scott-Moncrieff has introduced a compressed-air car on the Vale of Clyde tramways, particulars of which were given by Captain Douglas Galton in a Paper on "Street Tramways," read at the Society of Arts on the 7th of February, 1877. It is stated that this car travels a distance of three miles with each charge of compressed air at a cost of 3d. per mile, the consumption of fuel for compressing the air being estimated at three pounds per horse-power.

Compressed air has been used since 1864 in the shops of Messrs. Eastons and Anderson at Erith to work a hammer, riveting machines, and other tools. The pumps supply the air through 6-inch and 12-inch pipes, and are fitted with automatic contrivances for stopping them when the pressure of air rises to 40 pounds. The consumption of coal necessary to produce a given quantity of compressed air, by means of air-pumps driven by a condensing steam engine, is about sixty-nine per cent, more than to produce the same quantity of steam of a like pressure; for example, to produce 100 cubic feet per minute of air, at 45 pounds pressure above the atmosphere, would require 53 indicated horse-power, and a consumption of 159 pounds of coal per hour. To generate 100 cubic feet of steam at 45 pounds pressure,  $293^{\circ}$ , per minute, would require the evaporation of 845 pounds of water per hour, at the expense of 94 pounds of coal. The same firm have employed compressed air to pump the sewage at Windsor. They have also applied it in H. M. Dockyard

at Portsmouth to work capstans for hauling the largest ironclads in and out, and about the docks, as well as for opening the dock gates and sluices. It is understood to have been adopted there partly on the ground that it would not be exposed to the risk of damage through leakage, as either steam or water pressure might be, and partly because the power consumed would be more in proportion to the load to be moved than hydraulic power. As hydraulic power has been hitherto so extensively employed to perform operations of this intermittent nature, it will be interesting to know the results of using compressed air under the same conditions.

At the Tincroft mine a Doering drill was worked by compressed air, conveyed in a 2-inch wrought-iron pipe, down a shaft 1,200 feet deep. Observations showed that the pressure in the air-receiver on the surface was reduced from 26 pounds to 23 pounds at the drill when at work, and when standing idle the pressure at the drill rose to 28 pounds. At the Dolcoath mine, where the same drill was used, the loss between the engines and compressor when new was from 30 to 40 per cent., as ascertained by indicator cards on the pump and compressor.

Another and early method of transmitting power is by air exhaustion. About the years 1827-30 Hague exhibited a pneumatic crane which it was contemplated to apply to the St. Katharine Docks, with the view of seeing if the whole dock could be worked on that principle. Exhausted air has been employed for a variety of purposes, a well-known instance being its application to work the machinery at the Mint. The pneumatic system, in its application to the transmission of postal messages, was the subject of several communications to the Institution in the year 1875.

Where manual labor is used, as in working hand-power cranes, the cost of lifting and lowering goods is much greater than by other means. At Cotton's Wharf, London, a 10-cwt. crane lifting 40 feet requires on an average eight men at the handles, and it was found that the cost of lifting 100 foot-tons was 10.19d. (allowing 15 per cent. for interest and depreciation), and that the maximum speed of lifting the chain

without weight was 100 feet in three and a half minutes. The capabilities of the crane did not exceed 10 tons an hour, 40 feet high. Experience of late years at wharves and such places shows that men are difficult to keep to perform this class of work, and that an important diminution of energy is apparent in working hand-power cranes.

A comparison between manual labor and machinery has shown that the cost in the former is, in the case of cranes, about nine times that of the latter. Work done in collieries by hand is estimated by Mr. Emerson Bainbridge, Assoc. Inst. C.E., to cost about thirty-seven times as much as by machinery, and the diminishing rates of work done by men is shown by the fact that whereas in 1866 the number of tons of coal raised was 314 per man, in 1873 it was only 279, or more than 10 per cent. reduction.

Shafting is employed to transmit power within a limited area. The extent, however, to which it is applied may be judged by the fact that at the cotton mills of Messrs. Clark and Co., at Paisley, 4,000 H.P. are thus transmitted. Where the consumption is intermittent there are objections to shafting, as power is being constantly exerted to drive it, and in addition there are the wear and tear and friction, and the attention for lubrication and repairs necessitating the ready accessibility of the parts. The amount of power lost in transmission by shafting varies widely with the state in which it is maintained. M. Vigreux calculates that on a line of shafting running at 250 revolutions per minute, the loss due to friction of bearings is not less than 37 per cent. Several trials of engines for cotton mills and sheds, made by Mr. Joseph Clayton, of Preston, gave the friction of engine and shafting at about 32 per cent. of the gross load. A length of 300 feet of shafting working punching and shearing machines had been observed to consume 3.14 HP. In another case a length of 1,200 feet of  $2\frac{3}{4}$ -inch shafting absorbed 1 indicated HP. for every 100 feet of shafting, when the driving-belts were thrown off. In an extensive range of warehouses an engine of Messrs. Appleby's drives about 1,000 feet of shafting with a boiler pressure of 5 lbs. per square inch, the power being

transmitted by a vertical shaft and bevel gear from the basement (where the engine is placed) to the upper story where hoisting machinery is fixed.

The transmission of power by ropes, an extension of the belt and pulley method, will next be considered. M. Achard describes the transmission of motive power by wire ropes at Oberursel, near Frankfort on the Main. At this place a water-fall of 263 feet, discharging from 12 to 31 gallons per second, is utilized, and 94 HP. transmitted a distance of 3,153 feet, divided into spans of about 393 feet each, by means of a turbine actuating a wire rope working over pulleys 12.3 feet in diameter. The effective tension on the rope varies inversely as its velocity; it is 1,400 lbs. at the pulleys, and the velocity 73.8 feet per second. An advantage in transmitting power in this way is pointed out by M. Achard to be, that where the power has to be distributed amongst various lessees it can be controlled, and any attempt to take more than the lessee is entitled to would only result in the slipping of the rope, inasmuch as the power to be given out at any point depends on the tension.

Mr. Henry M. Morrison has given particulars of the employment of ropes as motors at Logelbach, in Alsace, where several printed calico factories, separated from each other, were supplied with 50 HP. from one steam engine, the power being conveyed a distance of 256 yards by means of light steel wire ropes  $\frac{1}{2}$  inch in diameter, passing over grooved pulleys of 9 feet 6 inches diameter, running at an average speed of 31 miles an hour. The loss sustained in transmitting 120 HP. 150 yards was estimated to be  $2\frac{1}{2}$  per cent. (or 3 HP.) due to friction of large pulleys. If the distance is greater supporting pulleys have to be used, which entail a further loss of nearly 1 HP. for every 1,100 yards. The direction of transmission has sometimes to be changed, and this is done either by directing pulleys, or by bevel wheels, the latter being considered the best.

Another instance of the employment of the wire rope system occurs at Schaffhausen, where, by constructing a dam across the river, the hydraulic power of the Rhine is utilized. Three turbines, 9 $\frac{1}{2}$  feet in diameter, are driven by a fall

of from 12 to 16 feet of water, and are capable of developing 750 HP., which is transmitted by iron wire ropes  $\frac{3}{4}$  inch in diameter, over grooved pulleys 15 feet in diameter running at an average speed of 100 revolutions a minute, or 53 miles an hour. The tension necessary to transmit 326 HP. is, according to M. Achard, 5,807 lbs. The cost of the power to consumers is stated to be about 40 per cent. below the cost of steam power.

Similar works have been carried out at Fribourg, where, by constructing a dam across the river Saane, the valley above is converted into a reservoir, and a fall of 34 feet 6 inches obtained. This fall is utilized both for the water supply of the town and to supply power to manufactories, the latter being obtained by a Girard turbine and 300 HP. transmitted a distance of 2,510 feet (divided into five equal spans of 502 feet) to the manufactories on the banks of the river by wire ropes. The pulleys are all 14 feet 9 inches in diameter, and make 81 revolutions a minute, which correspond to a velocity of 65 feet per minute of the rope. The tension necessary to transmit 300 HP. is 5,198 lbs., or 6 tons 10.6 cwt. per square inch on the rope. The loss of power in transmission by a single wire rope is estimated to be about 6 per cent.

The advantages accruing from these systems would appear to be not only in the use of rope transmission, but more particularly because the power is obtained without the use of fuel.

Comparing wire ropes running at high velocities with belting, shafting, and pipes for water or compressed air, the first cost is in favor of ropes. Mr. Morrison states that the cost of ropes is only  $\frac{1}{15}$  that of an equivalent amount of belting, and only  $\frac{1}{20}$  that of shafting. The wear and tear of ropes, together with the necessity of avoiding steep inclinations where the distances are long, lessen the advantage of that system; on the other hand, the loss of power in transmission by ropes varies only as the velocity, whereas either by compressed air or by water the loss due to friction increases as the square of the velocity.

Table 2, contains a statement of the transmission of power by wire ropes, compiled by Mr. W. A. Roebling, for

an article on that subject by Mr. Albert W. Stahl.\*

A report was made in the year 1869 by the North of England Institute of Mining Engineers on the four principal systems of underground haulage in collieries, namely, the tail rope, endless chain, endless rope No. 1, endless rope No. 2. These different systems are employed to suit the varying circumstances of the curves, gradients, and number of branches in the workings, and the results show that the amount of power absorbed in transmission is respectively 45, 25, 23, and 8 per cent.

The application of rope gearing, to transmit the power from the prime mover to machinery in a factory, in substitution of toothed gearing, has been recently advocated by Mr. James Durie. The friction of rope gearing for high speeds is much below that of toothed gearing, and it is considered to have advantages over belts, inasmuch as the power can be distributed over several ropes, either of which can be repaired without stopping the system; but where only one belt is employed, the whole of the system is stopped when the belt fails. The result of several experiments between flat leather belts and round ropes led to the conclusion, that the latter have a greater hold on V-shaped grooves per square inch than the former have on pulleys. Mr. Paget has found that the highest co-efficient of useful effect with the least wear to the rope is obtained when the angle of the groove is 40°, and at this angle Mr. Cowper gives the friction of the rope upon the two sides of the grooves as being three times as much as if the rope were working on the surface of a plain drum.

In considering the several means of transmitting power, it must be admitted that the convenience of a system of pipes to convey steam, water pressure, or compressed air, through the ramifications generally met with in supplying a variety of appliances, is great compared with shafting or ropes.

Compressed air, like steam, has an advantage over water when it can be worked expansively, as the power consumed by the appliances is then in proportion to the work done.

\* See Van Nostrand's Engineering Magazine, February, 1877, p. 171.

TABLE 3.—PRACTICAL RESULTS OF EXPERIMENTS WITH COMPRESSED AIR.

Pressures.		Work required to produce 1 cubic ft. Compressing apparatus giving 66 per cent. efficiency.	Work done by 1 cubic foot of air at pressure given, expanding to atmospheric pressure.		Percentage realized of work expended.			
Atmospheres above atmospheric pressure.	Lbs. per square inch above atmospheric pressure.		Without addition of heat during expansion.	With addition of heat.	Including both operations, viz., compressing and expanding.		Expanding only.	
					Without heat.	With heat.	Without heat.	With heat.
		Foot-lbs.	Foot-lbs.	Foot-lbs.				
2	29.4	4,401	1,366	2,156	30	44	45	66
3	44.1	10,458	3,048	4,648	29	44	44	66
4	58.8	17,577	4,962	7,812	28	44	42	66
5	73.5	26,451	7,028	11,756	27	44	41	66

TABLE 4.—THEORETICAL WORK DONE BY COMPRESSED AIR ACCORDING TO MARIOTTE'S LAWS which supposes that the temperature of the air remains constant throughout the operation of Compression and Expansion.

Pressure.		Theoretical work in 1 cubic foot expanding to 1 atmosphere.	Number of cubic feet produced by 1 HP. per hour.	Units of Heat equivalent to work given in third column. 1 unit=772 foot-lbs
Atmospheres above 1 atmosphere.	Lbs. above 1 atmosphere.			
		Foot-lbs.		
2	29.4	2,934	678.2	3.80
3	44.1	6,972	285.4	9.03
4	58.8	11,718	168.9	15.17
5	73.5	17,034	116.2	22.06

TABLE 5.—THEORETICAL WORK DONE ACCORDING TO POISSON'S LAW, which supposes that when air is compressed, none of the heat due to compression is allowed to escape, or *vice versa* when compressed air is allowed to expand, no external heat is added to it.

To reduce the given quantity to 1 cubic foot.			Work done by 1 cubic foot at pressures given, expanding to 14.7 lbs. per square inch.		
Cubic feet at 14.7 lbs per square inch.	Foot-lbs required.	Final pressure in lbs. per square inch.	Pressure in lbs. per square inch.	Work done in foot-lbs.	Final volume in cubic feet.
2	3,200	37.044	29.4	2,048	1.682
3	8,524	63.651	44.1	4,572	2.279
4	14,920	93.345	58.8	7,442	2.828
5	22,533	125.685	73.5	10,541	3.344

Steam must be considered to have economical advantages where the power has to be exerted continuously and within a limited area, and where the avoidance of fire risks is not essential.

At the usual pressure of forty pounds to the inch, it has been shown that, with compressed air, a loss occurs of about

fifty per cent. between the boilers and compressors. The loss in transmitting air is greater than that of water, owing to the volume of air, at forty pounds to the inch, requiring to be  $17\frac{1}{2}$  times greater than that of water at 700 pounds to the inch, to convey the same power. The friction varying as the squares of

the velocities, and directly as the densities it will be found that, after allowing for the density of air at forty pounds above the atmosphere being about 220 times lighter than water, the loss of power with air will be much greater than with water, the amount depending on the size of pipe.

Mr. Daniel, of Leeds, calculates that the useful effect of air, at forty pounds pressure per square inch above the atmosphere, is only 48.8 per cent. of steam at the same initial pressure. Table 3 gives 44 per cent. as the maximum percentage that can be utilized of the original power expanded, taking 66 per cent. as the efficiency of the compressing apparatus. Tables 4 and 5 give the theoretical effects at various pressures, according to Mariotte's and Poisson's laws. If the power necessary to compress air could be obtained without expense--as by a natural fall of water--the maximum useful effect would be 66 per cent. of the power expended.

Compressed air may be adopted with advantage in mining and tunneling operations, notwithstanding the small useful effect obtained, as it enables boilers and underground steam engines to be dispensed with, thus diminishing the risk of explosion; it further aids ventilation. On the other hand, steam can only be used in parts of the mine where the exhaust can be conveyed to the bottom of the upcast shaft, as both steam and heat act prejudicially on the stone, timber,

&c., in the workings. It also tends to the greater employment of labor-saving appliances, the introduction of which is productive of the double advantage of dispensing with manual labor and of enabling underground operations to be carried out more expeditiously, resulting in a quicker return on the capital sunk in such undertakings.

Systems of power co-operations, similar to that carried out at Hull, might advantageously be established to effect a better conservation of motive power by its concentration to supply entire districts. At present independent establishments are maintained to work the machinery and appliances, in most cases intermittently, thus involving waste of power, space, time, and money. By adopting power co-operation, the expense of production would be spread over many consumers, like the ordinary gas and domestic water services.

A comparison of the various systems shows that there are circumstances to which each is suitable, and that as these do not admit of being dealt with always on the same principle of economy, but rather of appropriateness, each case must be decided by the conditions governing it. Where, however, the work to be done is intermittent, as in the case of cranes and dock work, the hydraulic system, on the ground of speed, safety, steadiness, and general convenience, is considered by the Author to be superior to any other.

## THE RECORD OF 1877.

Condensed from "The Engineer," "Revue Industrielle," and "London Times."

THE year has not passed away without carrying with its chronicles the record of the completion of some great engineering works. The first among these belongs to our own islands, namely, the Tay Bridge. This bridge was commenced in 1871 and, owing to its magnitude and importance, much general interest has attached to it, and accounts of its progress have, during its six years of building history, made the public generally, as well as engineers, fully conversant with its object, and the chief features of its construction.

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Previous to the construction of this bridge the North British Railway Company paid a toll of from £10,000 to £12,000 per annum to the Caledonian Company on account of its traffic to Dundee; and in addition to this the company paid, as far back as 1869, a sum of £12,300 per year for Tay ferry charges. It has been estimated that the total gain secured by the structure will be £30,000 per year, the approximate total cost of the bridge and the short connecting lines being under £600,000. Of this the North British Company contributed

about £200,000, so that the undertaking, besides providing a direct communication between Edinburgh and Dundee, will be a source of profit. The bridge is only a little under two miles in length, and is thus the longest railway bridge in the world.

Another great work, which can only be said to have reached completion last year, is the Hoosac Tunnel; for although luggage trains ran through it as long ago as June, 1875, it has really only recently received the finishing touches. The tunnel is about four and three-quarter miles in length through the Hoosac mountains, and has been made for the purpose of providing direct railway communication between Boston, Massachusetts, and Albany, the capital of New York State. The cost has been defrayed by the State of Massachusetts, and the work has been of a difficult character, owing to the breaking and falling of the rock, most of which is of a slaty character, so that it has been necessary to line a very large portion of the tunnel with brickwork. The work has been in hand over twenty years but the erection of the east façade has only just been completed. The intention was at first to leave this unprotected by masonry, but the disintegration of the rock has rendered protection necessary. The work has cost about fourteen millions of dollars, including the small tunnel just completed at North Adams. Only one track is laid at present in the tunnel. The trains are run by telegraph, passenger trains being allowed ten, and freight twenty minutes to pass. Three lights, equi-distant, are affixed to the sides of the tunnel, dividing the distance into four sections. The lights are for the purpose of enabling the engineers to regulate their speed, and they are required to maintain a uniform space the whole distance. At the central shaft two lights are displayed, to indicate when the summit is reached and the grade declines, drainage being secured by making the tunnel 60 feet lower at each entrance than at the central shaft. The tunnel is never occupied by two trains at the same time, and no train is allowed to enter until the preceding train has made the exit. No equal distance of the road outside is traversed with so uniform speed, nor with so much safety, the track,

which a recent American paper observes, cannot be excelled, being perfectly straight. The roof of the tunnel is now considered perfectly safe, about a mile and one-third of brick arching having been built to sustain all doubtful parts, in sections from ten feet upward. Still the roof is under constant examination by men on the top of an elevated carriage which is propelled along the road. Admittance to visitors is strictly denied. Occasionally the tunnel is so free from fog and smoke that, standing at the central shaft, daylight can be discerned at both portals. A floor composed of oak, fourteen inches thick, let into grooves cut into the rock on a steep incline, prevents any pieces detached from the sides of the shaft from falling on to the track. At the summit of the mountain the opening of the shaft is enclosed by a stone wall twenty feet high.

Returning to works at home, and to one of less magnitude, some reference must be made to the completion of an undertaking which has been designed with the object of reducing the traffic on London Bridge—namely, the Thames Steam Ferry. This, it will be remembered, was opened on the 31st of October last, and had gradually gained sufficient public confidence to attract a good deal of traffic. About three weeks since, however, an accident happened which has completely stopped the use of the ferry. One link in one of the balance-weight chains broke, when two wagons and teams, which were delayed about five hours, were upon the southern pontoon. Happily the horses were good-natured, and looked upon the sudden conversion of their level footway into one at sufficient angle to cause their wagons to slide down to the side railings, as a matter of insufficient importance to call for any demonstrative proceedings. But the matter might have appeared very different to steeds of a different frame of mind, as, for instance, those which accompanied the late Lord Mayor across the river on the day of the opening. The breaking of this link also caused the breaking of the fixing flanges of one of the horizontal hydraulic cylinders, so that the pontoon could not be raised until the tide rose and lifted it. We have on several occasions stated our opinion that this ferry will not materially reduce the

traffic on London Bridge, but it has to be admitted that previous to this accident the ferry had secured considerable patronage. It will now however be about a month before traffic can be resumed, and though we do not mean to say that this sort of thing will necessarily happen very often, yet the fact that it has once happened will be looked upon by the public as very significant. It is no answer to say that steam ferry-boats conduct such traffic elsewhere, as at most places where river or estuary crossing is thus effected, no bridge is sufficiently near to form an alternative choice for those wishing to reach the opposite shore. Now that the stoppage has occurred advantage is being taken of the time to effect various modifications, such as strengthening the tail-boards of the boats, covering in the hydraulic cylinders, chains &c. We understand that no real difficulty was found in crossing the river traffic, and though we believe that nothing else than a fixed bridge will effect the desired relief of London Bridge, we think that it is much to be regretted that the chains were not properly tested prior to putting them to work, as if a sufficient test had been made the one faulty link would have been discovered.

Turning now to works in progress, we still find the most important within our own shores, and attention may be first directed to the Severn Bridge, of which Messrs. G. W. Owen and G. W. Keeling are the engineers, which is designed to connect the Great Western and Severn and Wye railways with the Midland. It is rather less than three-fourths of a mile in length, and consists of twenty-two spans crossed by bow-string girders varying in lengths between 134 feet and 327 feet, supported upon pairs of cast iron cylindrical piles, sunk by means of Reeve's pneumatic excavator before referred to. At the commencement of January last the foundations for twelve piers had been completed, ten of the piers had been carried to their full height, and eight spans of the superstructure erected. During the year seven other piers have been founded, and seven of the piers carried up to the under side of the girders. Seven spans of the superstructure have also been erected. The swing-bridge across the

Gloucester and Berkeley Canal is now being erected. This is of a total length of 196 feet, and will be moved by steam power, the engines and signal gear being placed in a house fixed on top of the bowstring girder forming the bridge. The works for the railway approaches are progressing with sufficient rapidity to insure their completion before the bridge is finished.

Another work of equal importance, and attended perhaps with greater difficulties, on the same river—or rather, beneath it—is the Severn Tunnel, of which Mr. Charles Richardson is the engineer. It is being constructed by the Great Western Railway Company to connect their system at Bristol with that in South Wales. The heading, which has been driven under the Severn from the Portskewit shaft, is now 1850 yards under the river. It has passed all the deep water, and is now under the bed of rock called the English Stones, which are dry soon after half-tide. As the river at this place is two and a-quarter miles wide, the heading is now nearly half-way across. The heading has run entirely in strong Pennant rock, with the occasional exception of small seams of clay-shale, and during the last month a bed of good hard coal about 18 inches thick. On first entering the Pennant, near the shore end of the heading, some heavy springs of salt water were met with, and these continue to flow at about the same rate up to the present time. It is a somewhat curious fact that this water contains only about one half the salt found in the water of the river above. Since the heading has been well under the river, the springs that are cut, though sometimes large when first tapped, invariably run nearly dry in two or three days, so that the amount of water to be pumped has not increased much for some time. The springs most recently met with have almost entirely lost their saltiness, and the water is pleasant to drink, these springs being under the middle of the river.

Since the end of February last the average weekly rate of progress of the heading has been forty-seven feet in-

cluding all stoppages. A permanent shaft for pumping has been sunk near the present shaft at Portskevit. This is now being lined with cast iron tubing, and one of the large pumps is being fixed at the same time, a second large pump being in preparation. The whole of the water coming into the tunnel will eventually run to this shaft. A contract has been left for sinking three working shafts; these will be started as soon as the land arrangements have been completed. These are all the shafts that will be required, as it has been decided not to put one in the river. The heading will be completed throughout before the larger works are begun, and this will without doubt be economical in many ways.

The London Victoria Docks Extension Works have made material progress, and the works are in every respect proceeding as rapidly and favorably as possible. Of the general excavations, some two millions out of about two and three quarter millions of yards have been excavated and sent to bank. The line designed to carry the North Woolwich branch of the Great Eastern Railway under the extension is being rapidly pushed forward, and the tunnel in connection with it is in itself a fine piece of engineering. For a portion of the way it is a double tunnel, and this has been completed, while the remainder is far advanced, as well as the open cuttings forming the approaches. Should the same energy and skill be maintained as the contractors have shown up to the present time—and from their well-known character there is no reason to doubt such will be the case—these docks will in all probability be opened early next year, and an enormous addition will thus be made to the capabilities of the port of London.

At Chatham great progress is being made in the extension of the dockyard, which will make this naval yard the finest and most important in the whole world. The works have been in hand many years, and some four or five more are likely to pass before the whole is completed, notwithstanding the fact that there are between 1,400 and 1,500 hands employed, the great majority being convicts. The cost of the enlargement when complete will be considerably over

£2,000,000, and already about £1,800,000 have been spent upon it. The original estimate of the cost was £1,950,000, but that estimate will be largely exceeded. The extension consists of three immense basins, which will have a combined area of 74 acres, and four large graving docks, sufficiently large to accommodate the largest vessel that is ever likely to be built. All the basins—repairing, factory, and fitting out—are to be connected, so that a vessel on being launched can be floated into the former and taken out of the latter, fully equipped for sea. The first is 21 acres in extent, and opens into the Medway nearly opposite Upnor Castle, the mouth of the basin being eighty feet in width. The whole of the four docks abut on this basin, and have been in use some time. The factory basin is twenty acres in extent, and it is intended to erect extensive workshops on the wharves for the construction and repair of engines and boilers, as well as the principal workshops required in iron shipbuilding. Shears capable of lifting 100 tons have been erected on the walls of this and the repairing basin.

Referring now to projected works, those of greater magnitude directly of interest at home are for the supply of water. The opposition to the Thirlmere scheme has conversantly placed the proposed method of water supply for Manchester before the public, though it has at the same time been the means of disseminating very erroneous and rather one-sided views. It is scarcely possible that any opposition was ever backed by more careless statements, and by half-knowledge of the facts of the matter, than those which have characterized the asseverations of the self-appointed defenders of Thirlmere. Like many other sheets of water in the Lake District, Thirlmere is privately owned, and the rights of property have been almost as rigidly exercised as they are by the possessors of some of the others from which visitors are strictly excluded. Some of these possessors and their friends are the lovers of nature, "with a circumstance," who talk of the desecration of the lake, and lead others to write about the destruction of natural scenery, which, as far as nine-tenths of the population of this country, or even of the visi-

tors of the district are concerned, might as well be at the farther side of the moon, for it is seen with difficulty, and then only from a few points. The part of the lake, moreover, which is really the most beautiful is hardly ever visited. A much frequented public road, it is true, runs past a portion of the lake, but under existing conditions it is only from this that it is seen by a great majority of the tourists to the district, and it is very strange that, until Manchester found that water of equally good quality and the absolutely necessary softness could not be obtained in sufficient future quantity elsewhere, the exquisite beauty of Thirlmere was little known or appreciated. But it is even more strange that all argument, or rather all opposition, has been based on the exaggerated statements of those who assume that because the lake water is to be used, and that an embankment is to be placed at a never visited site at one end, that the scenery of the whole lake and its district is necessarily to be destroyed. The level of the water in the lake is to be raised by fifty feet, but because the lake will be larger and deeper, need it be less beautiful? Its shores will be of the banks already existing, and without alteration. It has been made much of that the lake is one of the people's beautiful resorts for recreation, yet no one is allowed to roam freely on its borders or row a boat on it, and fishing has been stopped for many years. If it could be shown that Thirlmere and the district surrounding it would be really injured, we should speak differently on the subject, but no trustworthy evidence is yet forthcoming that danger exists.

A railway across the Sahara has been seriously proposed and the idea entertained in France. In 1874 M. Paul Solielliet proposed a line from Algeria to the Niger, and thence to the Senegal, thence opening up a large portion of Soudan, which contains a population of about thirty-eight millions of people. Recently M. Duponchel has been sent out by the French Government to study the country with a view to a railway, and his proposal is practically that of M. Solielliet. The line would be about 2500 kilometres to the point at which it joined the Niger, and it would, it is estimated, reduce the cost of transport of freight

between Algiers and Timbuctoo, for instance, from 40 centimes per kilogram-meter to 10 centimes. Altogether between 11,000 and 12,000 kilometers of railway have been proposed, almost the whole of which would be through easy country.

Railways in China are again among the works of the future, for the Woosung and Shanghai line has been paid for by the Government, and its working stopped. It is impossible, however, even in China, that, having once seen the advantages which railways may confer, conservatism can long prevent their adoption. The Darien Inter-Oceanic Canal scheme has made a little progress during the year, but it is still a paper proposition.

Nothing very remarkable in mechanical engineering has been effected during the past year; but there are not wanting indications that invention has not quite died out among us. As regards the steam engine especially, it is daily becoming more and more evident that the principles involved in the action of steam as a power producer are becoming better understood, and as knowledge is increased, so will improvements be effected in the construction of steam engines. A great deal is being done to impart accurate ideas concerning what we may term the philosophy of the steam engine, by competent engineers carrying out experiments and publishing the results. For example, a report such as that proposed by Mr. Lavington Fletcher on the performance of an engine and boiler at Dalkeith, and published in *The Engineer* last August, cannot fail to do good. The millstone which has hitherto hung round the neck of all those who really desire to reduce the consumption of fuel in steam engines, has been ignorance of the true nature of the fluid with which they had to deal. Until a comparatively recent period steam has been regarded by engineers, and treated by philosophers, as a permanent gas, whereas it is really a most unstable fluid, never met with free from water except under conditions which practically prohibit its use as a power-producer. Acting on the theory that steam would follow Mariott's law when expanding in a cylinder, men assumed that there was hardly any limit to the economy which might be

obtained by carrying out the principle of expansion to its furthest extent; and the failure which invariably followed all attempts of the kind was explained away by almost any hypothesis save the right one. It is not too much to say that Mr. Isherwood, of the United States navy, in his masterly preface to the second volume of "Experimental Researches in Steam Engineering," was the first who had the courage to dispute the soundness of this vicious theory. In the volume in question, published in Philadelphia in the year 1865, he showed that steam could not behave as a permanent gas in a metallic cylinder, and that there was a limit to the gain to be derived from expansion which was very speedily reached. The accuracy of his views was eagerly disputed in this country; but time has demonstrated that his conclusions were all sound in the main, albeit tinctured with a little prejudice. The now celebrated Gallatin experiments, which have been fully reported in these columns, showed that heavy loss followed on the adoption of measures of expansion as great as ten to one. Ample evidence to the same effect has been forthcoming at home. Engineers, who are sufficiently large-minded to abandon old prejudices, begin to recognize the fact that it is worse than useless to rely on expansion alone as a means of realizing economy of fuel, and that it must be sought in other directions. What these are we propose to indicate here, in the hope that what we may say on the subject may prove useful to those who may set about effecting real improvements in the steam engine during 1878.

The fact to be borne in mind above all others is that steam readily loses heat and condenses, but that it absorbs or takes up heat with much reluctance. An engine to be truly economical must have a condenser, but this condenser tends powerfully to rob the cylinder of its heat. In fact, the condenser is little else than an extension of the cylinder, and it is by no means easy to keep the one cold and the other warm. The principal object to be effected by the engine builder is to prevent the condensation of steam; and this end can be best secured by jacketing the cylinder, by clothing the jacket, by compressing the exhaust steam at the end of the stroke, and by using

separate ports and valves for the ingress and egress of the steam, these passages being so arranged that water may continually drain from, instead of into, a cylinder. We have often stated that little economy follows the use of a jacket, and we see no reason to alter this opinion so long as jackets are made in the ordinary way and applied to engines of large dimensions and the usual proportions. But it is not to be disputed that when engines are made with cylinders of moderate dimensions, say up to thirty inches diameter, and with long strokes, economy may be promoted by the use of a really efficient jacket. In the great majority of cases a jacket is of no use whatever save in so far as it acts the part of lagging to the cylinder, because, in the first place, it does not include the cylinder covers, and because, in the second place, the walls of the cylinder are so thick that the steam in the jacket has not time to prevent the condensation of moisture on them, and if this takes place, then farewell to economy. The walls of a cylinder ought to be so thin that heat can traverse them with great rapidity. If it were possible, they should not exceed a thickness of one-twentieth of an inch. This is out of the question, of course; but it is not impossible, we think, to produce steel liners which for a thirty-inch cylinder need not much exceed a thickness of one-eighth of an inch, the liner being supported by suitable ribs in the interior of the cylinder. Be this as it may, it will be found worth while to make the attempt. Again, all ports and passages should invariably open into the bottom of a horizontal cylinder, and the exhaust should never take place through the influx port. It is almost beyond question that the economy of the Corliss engine is due in great measure to the use of two sets of ports. Compression, again, although it reduces the total power of an engine, augments its economical efficiency by preventing at the end of each stroke evaporation from the wetted surfaces, and by compensating for loss by clearance. We have only space to glance hastily at these points. They may appear to be trifling, but it is on the attention which is paid to them that economy really depends. Before taking leave of this por-

tion of our subject, we would protest against the error that increased economy can be secured by the use of extreme pressures. This is a dangerous delusion, which is producing marine boilers with shells  $1\frac{1}{4}$  inch thick. It is simply an *ignis fatuus* which has been followed since the days of Trevithick, and has always ended in disappointment. Nothing can be more certain than that the greatest admissible ratio of expansion is about eight to one. If elaborate experiments and investigations have ever proved anything they have proved this. There is not in existence a single trustworthy record of an experiment which proved that it was more economical to expand steam twelve times than eight times in any engine; nor will such a result be obtained until a non-conducting cylinder is produced. Now the economy due to any given measure of expansion is independent of the initial pressure, that is to say, we shall have, *ceteris paribus*, the same result whether we expand 50 lbs. or 100 lbs. steam, say, four times. The limit to expansion is to be measured always at the lower or condenser end of the scale. If we take the terminal pressure as 8 lbs. on the square inch absolute—and this is about the best with ordinary condensers—then it is clear that with an eightfold expansion the initial cylinder pressure should be 64 lbs. absolute, and the load on the safety valve may be 60 lbs. per square inch, or 75 lbs. absolute. If, however, it was practicable to reduce the terminal pressure to 6.4 lbs., then the range of expansion might be augmented to ten times without increasing the boiler pressure; whereas, if we want to expand ten times, the terminal pressure being 8 lbs., we must increase the initial pressure to 80 lbs. In other words, by reducing the terminal pressure 1.6 lbs. we get precisely the same result as though we augmented the boiler pressure 16 lbs. Thus it would be far better for engineers to endeavor to obtain better vacuums than to increase boiler pressures; and if as much attention was paid to condensers as is now devoted to boilers, this end would be obtained and fuel saved. Few marine engines after they have been a little time at work carry more than 24 inches or 25 inches of vacuum, while 27 inches or

27 $\frac{1}{2}$  inches might be had under different arrangements. Finally, the progress of improvement in steam engineering should take the direction we have sketched—that is to say, every effort must be directed to keeping the inside of the cylinder dry; and if this end be secured the rest will follow, provided proper care is taken to supply the engine with pure steam economically generated.

During the past year but little was done towards the introduction of steam power on tramways. Up to the present moment it would seem that Mr. Hughes, of Loughborough, has been more successful than any one else in constructing engines for this purpose. A somewhat novel form of engine constructed by Mr. Brown, of Winterthur, is being used on the Paris tramways. But very slow progress indeed is being made in the right direction in this country. The experience obtained in Paris indicates that it may be quite possible to dispense with condensing arrangements, and that all devices which conceal the men in charge of the engine are prejudicial, inasmuch as horses will not take the alarm if only they can see men, while they are intimidated by the movement of large covered vehicles apparently without human agency.

In no department of mechanical engineering is there a greater demand for energy just now than in the design and production of machine tools and labor-saving appliances. In this respect our American competitors have a great advantage over us. A firm engaged in the production of any article which can be made almost wholly by machinery, is to a large extent independent of human labor; he can laugh at strikes and realize a good profit where others can hardly make both ends meet. As an example of what may be done in this direction, we may cite the American Waltham watch, said to be equal in quality to the best English watch, and made wholly by machinery. The Enfield Small Arms Factory supplies another example. In one case a large manufacturer of implements has carried the machine tool system to such perfection that he employs none but ordinary laborers, such as may be found in almost any agricultural district. Unfortunately, engineers have not hitherto availed themselves sufficient-

ly of tools, and those tools which they do use are too often defective in one essential particular. We allude to the means provided for putting work into a tool and adjusting it. More time is frequently spent in getting an article to be bored, placed and secured than is subsequently required to do the boring. The ordinary arrangements for fixing work on face-plates, plane beds, and such like are often disgraceful to the skill of the age, and any tool-maker who will turn his attention in this direction, and effect a change for the better, will do much to help his countrymen to contend against competition and strikes.

In the mechanical engineering of warfare we appear to be as far from finality as ever. We have so recently described the existing condition and prospects of the gun v. armor-plate controversy, that we need say little concerning the novelties in armor-plating which are likely to be developed during the present year. We may, however, call attention to a fact which it is not unlikely may be overlooked. It is that there are three elements in the armor-plate and gun contest, namely, the gun, the projectile, and the plate. Once the shot has left the gun, the latter has no more to do with the matter, and the fight is carried on subsequently between the shot and the plate. Now the danger is that the shot may be neglected, while we go on increasing the power of gun and armor. Already there are indications that the plate is likely to prove too much for the projectile, although it would easily succumb to the gun. Thus we can tell accurately how many foot-tons of work must be in the shot to enable it to get through a given plate; but if much of this work is expended in breaking the shot, so much less will be left to perforate the plate. There is reason to believe that chilled projectiles will ultimately have to give way to something stronger, and this something is obviously steel.

In the mechanism of the iron manufacture little if anything has been effected that is new during the last year; nor do we see that much prospect exists that any important changes will be introduced during the present year. In machine puddling but slow progress is being made, and the general drift of

opinion is that the days of puddling, at least in the ordinary sense of the word, are numbered. Steel is to be the metal of the future, or at least iron produced by what may be called a steel process. It is, however, too soon to speak very decidedly on this subject. We may say, however, that it is improbable that any very remarkable novelty in the mechanical engineering of the iron manufacture will be introduced during the ensuing year. As bearing with much importance on the development of the steel industries in this country, we may call attention to the circumstance that Lloyd's have agreed to sanction the use of steel in shipbuilding. We have already referred at length to one circular on the subject, issued by the association, and the following extract, from a second report just issued, will show precisely how the matter stands at present. Our readers can judge for themselves from this what progress the employment of steel in shipbuilding is likely to make during the year. "After making the fullest inquiries," says Messrs. Martell, Cornish, and John, "it is gratifying to be able to state that the Committee's circular, recently issued on steel for shipbuilding, appears to have met with very general approval. At the same time, after a most careful consideration of the subject in connection with our recent visit, we are of opinion that the circular would be improved and the Committee's objects be more fully carried out by the following alterations and additions, which we also believe would be cordially accepted by the manufacturers and others interested:—(1) A special brand should be required to be legibly stamped in two places on every plate and angle, and this should in each case be recognized by the manufacturer as denoting on his part that the material is capable of withstanding the Committee's tests, and that a shearing from each plate or angle so marked had already been satisfactorily submitted to the temper test required by the circular. (2) The limits within which the tensile strength is fixed might with advantage be raised so as to become from 27 to 31 tons per square inch. (3) The elongation of 20 per cent. required should be fixed for a definite length of 8 inches, or if a shorter length be taken for testing, the percentage of

elongation should be correspondingly increased." Mr. Parker, chief engineer surveyor to Lloyd's, is carrying out a series of experiments on the manipulation of steel for boilers, with a view to the preparation of a report, which, coming from Mr. Parker, can hardly fail to prove very valuable.

One of the earliest incidents in the past year was the appearance of the report of the Special Committee of the Local Government Board on the several modes of treating town sewage. The Committee consisted of Mr. C. S. Read, M.P., and Mr. Rawlinson, C.B., assisted by Mr. Smith, the Secretary to the late Rivers Pollution Commission. The general tenor of the report was unfavorable to chemical processes for the treatment of sewage, and the Committee stated that "The application of town sewage to land is shown in this report to be the cheapest mode of disposing of it." Nevertheless, the Committee acknowledged "that land irrigation is not practicable in all cases; and, therefore, other modes of dealing with sewage must be allowed." But the report failed to recommend any "other mode," unless it were to be found in the statement that "towns situated on the sea coast or on tidal estuaries may be allowed to turn sewage into the sea or estuary, below the line of low-water, provided no nuisance is caused." Undoubtedly any method of treating sewage, however summary and wastful, which causes no nuisance, is to be tolerated, if not commended. The appearance of this report produced no great sensation, and does not appear to have assisted the sewage question in any marked degree. In the month of February a deputation from the Society of Arts, headed by Lord Alfred Churchill, waited upon the President of the Local Government Board, and seriously astonished Mr. Sclater Booth by stating that not more than three-fourths of the houses in the metropolis were connected with the main drainage system. In return, the deputation themselves received a surprise, on being informed by the President of the Local Government Board that he had nothing to do with the drainage of the metropolis. The subject was one for the Home Secretary. The deputation suffered further discouragement on being told by the Presi-

dent that he "was not one of those who was disposed to find fault with the government of London," adding "he thought it was much more easy to find fault than to suggest remedies." As the deputation were evidently a little at sea on the subject, they "withdrew," having accomplished nothing beyond learning a little more than they knew before. One feature of the sewage question which has lately become prominent is that of combination among districts for the purpose of carrying out large intercepting works. Cases of this kind present themselves in the Thames Valley and elsewhere. In May, the Society of Arts held a conference on the health and sewage of towns, and a summary of returns from a large number of places was laid before the meeting by Mr. P. Le Neve Foster. In Parliament, a bill introduced by the Government, for consolidating the laws relative to the health of the metropolis, was withdrawn towards the close of the session, considerable opposition having been offered to the measure, on the ground that it gave the Local Government Board power to over-rule the local authorities. In the autumn the Local Government Board issued a circular, addressed to the various sanitary authorities of the kingdom, explanatory of the provisions of the Act for Preventing the Pollution of Rivers. The Act was passed in 1876, but its penal clauses remained in abeyance for twelve months. At the annual meeting of the British Association a valuable paper on certain laws of population was read by Dr. Farr, making it sufficiently clear that sanitary reformers need not be checked by the fear that the globe was in danger of becoming overpopulated. At the Social Science Congress at Aberdeen, Mr. Edwin Chadwick, C.B., gave an address on "Health," in which he cited a number of facts to show the success which attended sanitary measures when these were thoroughly carried out. In the month of October the Sanitary Institute of Great Britain held a congress at Leamington, when Dr. Richardson delivered an address in support of his theory that the poison productive of so-called "zymotic" disease is in no case a germ, but is the result of a disturbed glandular action, bearing a general resemblance to snake-poison.

Hence a patient suffering from a communicable disease, such as scarlet fever, is simply regarded as "a poison-producing animal," temporarily brought into a condition analogous to that of a poisonous snake. How far this theory may affect the progress of sanitary measures we cannot pretend to say, but the past year has been witness to a considerable amount of controversy over the germs, in which Professor Tyndall, Dr. Bastian, and Dr. Burdon Sanderson have been conspicuous. Whatever the nature of the process, there has been a remarkable persistence in the outbreaks of typhoid fever in royal residences and public offices. Marlborough House has only lately been made fit to live in, and the public are at length congratulated on the fact that all the abodes of the British Royal family are free from poisonous gases. The latest phase of the sewage question consists in a report from Captain Calver, on behalf of the Thames Conservancy Board, announcing that the sewer outfalls of the metropolitan main drainage works are seriously polluting the river, and silting up the channel. Sir Joseph Bazalgette disputes the fact, and an official statement on behalf of the Metropolitan Board of Works is understood to be in course of preparation. During the autumn, some inquiries have been conducted by Mr. R. Rawlinson in provincial towns, under the Pollution of Rivers Act, and it is probable—or possible—that in the course of the incoming year some practical results will accrue from the new law, but it is by no means easy to say what direction they will take. It is at least certain that enough remains to be done to give ample employment to sanitary engineers for years to come, if only the requisite funds are forthcoming; and it would also appear that the questions connected with the chemical purification of sewage are by no means yet set at rest. In other words, a perfectly efficient and satisfactory process of the kind is wanted. Such a process would go far to extract local boards from a host of difficulties which still surround them.

In considering the year's work in the science and practice of electricity, we are inclined to give the first place to those methods of applying our knowledge which seem to us calculated to give the

greatest good to the greatest number. A few years ago even thinking minds thought it wonderful that a message could be sent by means of a wire and a dirty-looking trough; but "familiarity breeds contempt," and the youngest amongst us sees nothing wonderful in it now. We are, however, going far beyond the sending of a message, so that for some time past two messages have been sent on the same wire at the same time. The duplex system is now being superseded by the quadruplex system, by which no less than four messages can be transmitted along the same line-wire at the same time. During the past year the quadruplex system has been introduced into England, and is being tested by the Government, with a view to its more extensive application. In a *résumé* of this kind it is impossible to enter into details which require diagrammatic illustration, but there are one or two sentences it would be well to quote to show the principles employed. In a paper published in June, 1873, Mr. O. Heaviside pointed out that the invention of a system of simultaneous transmission in the same direction furnished the solution of the problem of quadruple transmission. "It is," he says, "theoretically possible to send any number of messages whatever simultaneously in one and the same direction *upon a single wire*"—the italics are ours. Now, by combination with a null duplex system, it obviously becomes possible to send any number of messages in the other direction while the opposite correspondences are going on, and without interference. Thus the working capacities of telegraphic circuits may be increased indefinitely by suitable arrangements." Messrs. Edison and Prescott of the Western Union Telegraph Company, seeing that the duplex system was destined to lead to something more, experimented and modified till they had devised a system materially differing from all previously in use, and which formed the basis of a system which was the "first practical solution of the problem of quadruplex telegraphy." Mr. Prescott, in his address before the Society of Telegraphic Engineers, said: "The distinguishing principle of this method consists in combining together two distinct and unlike methods of single transmission, in such a manner that

they may be carried on independently upon the same wire and at the same time without interfering with each other. One of these methods of single transmission is known as the single current, or open circuit system. In the double current system the battery remains constantly in connection with the line at the sending station, its polarity being completely reversed at the beginning and at the end of every signal without breaking the circuit. The receiving relay is provided with a polarized or permanently magnetic armature, but has no adjusting spring, and its action depends solely upon the reversals of polarity upon the line, without reference to the strength of the current. In the single-current system, on the other hand, the transmission is effected by closing and breaking, or increasing and decreasing the current, while the relay has a neutral or soft iron armature, provided with a retracting spring. In this system the action depends solely upon the strength of the current, its polarity being altogether a matter of indifference. It will therefore be apparent that by making use of these two distinct qualities of the current—viz., polarity and strength, two sets of instruments may be operated at the same time on the same wire. This method possesses, moreover, the important practical advantage that the action of each of the two receiving relays is perfectly independent. Each receiving operator controls his own relay, and can adjust it to suit himself without interfering with the other." It will thus appear that although all difficulties are not yet overcome, we are fairly on the road to utilize to a much greater extent the lines already in existence. It is needless for us to point out the value of quadrupling the carrying power of lines between populous centers of industry where time is in reality money.

The majority of readers, if not of writers, would probably have spoken of the telephone as the most prominent and useful of the newer adaptations of telegraphic science. Wonderful as it is, we think it must take second place. Since the publication of an article on the telephone in *The Engineer* for July 20th, 1877, Prof. G. Bell has delivered several lectures on this instrument, and great efforts are being made to give it a per-

manent place in our midst. Several important uses have been found for it, among which we may mention that in mining operations, to enable the manager of a mine to ascertain the rate at which the air current is passing through the workings. The telephone is made to repeat the sounds produced by a spring vibrated at every tenth revolution of an anemometer by suitable mechanism, the spring being placed in close proximity to the pole of a magnet, where it vibrates without touching the magnet. A coil surrounding this magnet is joined up in the usual way to wires leading to the telephone, and it is found that every "tick" of the steel spring is heard in the telephone. This application is the invention of Messrs. Le Neve Foster and H. Hall. It seems to us that the invention can easily be extended to the recording permanently of the velocity of the wind. Whilst experimenting in one direction there seems to be an absence of experiment in another. Photography is utilized at Greenwich, Kew, and other observatories to record the magnetic deviations, i.e., motions of a magnet. True, some of these motions are slow, but not always, so that a more sensitive paper would possibly be acted upon by light influenced by vibrations. For some years our thoughts and experiments have tended in this direction, and, as we say, there is plenty of room for investigation. The other application we have referred to is that for the use of divers. A telephone of suitable construction is placed in the diver's helmet and connected to the wire which serves to expand the air pipe. Experiments made with this arrangement in Messrs. Siebe and Gorman's tank were perfectly successful.

Whilst giving due credit to Prof. Bell for his discoveries, we must not forget that others have invented telephonic apparatus besides Prof. Bell, and they should not be forgotten. Mr. Edison has invented a speaking and recording telephone, which has been noticed in our columns. But Mr. Edison has invented even a more surprising instrument, which we hope to describe and illustrate at an early date. Meanwhile, the following remarks from the *Scientific American* will be read with astonishment:—"Mr. Thomas A. Edison recently came into this office, placed a little machine on our

desk, turned a crank, and the machine inquired as to our health, asked how we liked the phonograph, informed us that *it* was very well, and bid us a cordial good night. These remarks were not only perfectly audible to ourselves, but to a dozen or more persons gathered around, and were produced by a very simple mechanism. Across the inner surface of a mouthpiece is a metal diaphragm, and to the center of this diaphragm is attached a metal point. A brass cylinder is so adjusted as to revolve on its bearings by a screw-thread, working in a nut, so that when revolving it has also a horizontal travel in front of the mouthpiece. The point of the diaphragm, when the latter vibrates, describes a spiral trace over the surface of the cylinder. On the latter is cut a spiral groove of like pitch to that on the shaft, and around the cylinder is attached a strip of tin-foil. The foil where it passes over the groove in the cylinder is easily indented, and these indentations are necessarily an exact record of the sounds which produced them." Given the indentations caused by the vibrations, it was necessary to convert them back again into the vibrations, and this Mr. Edison does by another diaphragm and a metal point, the latter being held against the tin-foil in the cylinder by means of a delicate spring. Of course the action of the point against the indentations causes the diaphragm to vibrate and to reproduce the original sounds. The sounds need not be reproduced immediately but may be sent forth again after the lapse of any number of years, so that a voice uttering sentences now may be heard in future ages, when the utterer has long passed away and been forgotten.

Prof. Dolbear also has a telephone, which, although not so simple as some others, is interesting. He uses three horseshoe magnets, above six inches long, and strong enough to hold up several times their own weight, and two bobbins with insulated wire. These bobbins are about  $\frac{1}{2}$  inch long and  $1\frac{1}{2}$  inches broad. Through the center of the bobbin a hole  $\frac{1}{8}$  inch in diameter is bored, into which a piece of soft iron is fitted in such a manner as to project slightly on one side, but further on the other, which is firmly clamped between the magnets. The bobbins are

wound with as much as they will hold of insulated copper wire, of about  $\frac{1}{16}$  inch thick. The three magnets are superposed one on the other, the center of the three being drawn back, so as to admit the ends of the soft iron rods on which the bobbins are fitted. The magnets rest on a wooden block mounted on a stand, and a screw holds them firmly and clamps the rods carrying the bobbins, which are pinched between the upper and lower magnets. The wires are connected as they would be to make opposite poles of their outer ends when a current is sent through them. Vertically in front of the bobbins is fixed a board with a hole cut in the center, over the hole a piece of thin sheet iron or steel being tightly screwed. When the instrument is used as a receiver, a short tube of about 2 inches in diameter may be made fast to the front of the board in a line with the center of the plate. The action of this ingenious apparatus will easily be understood by our readers. Some experiments have been made with telephones connected with cables, but the most rudimentary knowledge of electrical science is sufficient to show that the invention cannot be used over cables of any length. The longest hitherto tried is that between Holyhead and Dublin—less than seventy miles—and then the sound appeared muffled, as if spoken through a respirator, instead of being clear and distinct. In reasoning about what may occur in a cable, one is compelled to consider both the inductive and the conductive action, and although the telephonic action takes place through a conductive circuit of hundreds or thousands of miles in length, the action cannot generate sufficient quantity to overcome a comparatively small induction. The cable has, so to speak, to be filled with electricity, and the telephonic apparatus fails to comply with the requirements. Thus its use is restricted to overhead wires or short underground wires and cables. We have heard described a very plausible, but indirect, means by which sounds might be transmitted at a very great expense through long lengths of cables by an extension of Bains' chemical process as applied by Mr. Edison in his motograph. The telephone acts perfectly through such a short cable as that between Dover and Sand-

gatte, as was proved by the experiments made on Dec. 29th last. According to Dr. Muirhead, who has carefully tested the instrument by means of his artificial cable, the limit of action is soon reached. His experiments were made through a length of artificial cable of the type of the Direct United States Cable, so constructed that inductive or conductive action could be added at will. In speaking by telephone through a hundred miles of this cable, with conductive current only, the words were comparatively loud and distinct, but the instant induction was added the voice lost both power and distinctness to a remarkable degree. It appeared only half as loud as before, and dull and smothered in tone. With a hundred and fifty miles of artificial cable, while the voice was apparently as strong as ever through the resistance circuit alone, it was completely silenced by putting on the capacity. Even with the best telephone, the extreme limits of articulation by direct means would be less than two hundred miles. Theory points out, and experiment verifies the fact, that a long-continued sound will be to a certain extent transmitted, and thus singing can be heard through a greater length of cable than talking. In the latter the duration of the sound is short, and a sufficient time is not given to allow the inductive action to be overcome.

It may be interesting to have some conception of the relative position of various countries as regards telegraphic convenience. The latest statistics give:

	Miles of line.	Offices.	Sq. m. of area.
England.....	75,000	5600 or 1 mile of line to every	1½
France.....	28,800	2370	7
Italy.....	12,600	1400	9
Austria.....	28,000	2900	9
Germany.....	19,100	3300	11
United States.	79,000	6850	36
British India.	15,700	225	60
Turkey.....	17,600	400	105
Russia.....	31,500	900	330

Electricians regret the loss of Henry Daniel Ruhmkorff, whose name is closely connected with the history of magneto-electricity. The famous "Ruhmkorff coil" first appeared in 1851, and for the invention he received a decoration and medal in 1855, and in 1858 the first prize of 50,000f. at the French exhibition of Electrical Apparatus. Herr Ruhmkorff died suddenly on December 20th, at Paris. We also lost Mr. Bain in the early part of the year. He was one of the giants in electric discovery.

THE *Revue Industrielle* says of discoveries and labors in physical science:

"The last months of the year just closed were distinguished by a succession of remarkable exploits in the domain of the physical sciences. The scientists of the United States were particularly distinguished by their labors. The old continent can produce nothing to compare with the discoveries of the satellites of Mars; the presence of oxygen in the sun; and the Telephone."

In France the most interesting scientific event was, without doubt, the liquefaction of gases. M. Cailletet of Chatillon-sur-Seine and M. Pictet of Geneva, working independently of each other, have succeeded in reducing oxygen, nitrogen, nitric di oxide, carbonic oxide to true liquids, and hydrogen to a cloudy, vaporous condition.

The results were obtained by the combined effects of a pressure of 200 to 300 atmospheres, and a temperature of 30°C.

It may therefore be stated that the last of the gases have yielded to the skill of these savants and that all known aeriform bodies have been exhibited at sometime or other in the liquid form.

Of the decline of the trade in coal and iron the *London Times* says:

"There is hardly any aspect of national suffering more painful than the fall of a great industry into melancholy and forlorn stagnation. Such a calamity is usually to be traced directly to some palpable mistakes in policy on the part of either capital or labor, or both; and it lacks the tragic dignity which clothes the visitations of plague, pestilence and famine. In the latter, too, there is always a gleam of hope behind the darkest cloud; the most merciless epidemic, the most cruel scarcity, must, we know, some day slacken and soften, and finally pass away. But when a great industry is smitten, there is no guarantee that it will ever revive on the ground where it once had flourished. A new demand will, no doubt, spring up, but in the meantime new sources of supply may be opened, and to these, by preference, commerce may resort. Thus it happened with the Thames shipbuilding trade. We sincerely trust that a better fortune is in store for the iron trade, which is now passing through a period of depres-

sion that in some parts of the country involves extreme misery among the working people. The misfortunes of this industry have contributed to produce similar and even more grievous distress in the coal districts of South Wales. We published the other day some particulars of the state of the South Wales collieries, where the price of coal has fallen far below a remunerative standard, and the production is, notwithstanding, vastly in excess of the demand. At Cardiff Docks, it is stated, there are 'miles of laden coal wagons waiting for shipment,' and the exportation has fallen off within half a year from 363,000 tons a month to 215,000. At Newport the falling off is computed to be 20,000 tons a month, and at Swansea, 10,000 tons. All along the Rhondda Valley, where the output of coal is the greatest in the whole of South Wales, the collieries barely keep at work, for the masters allege, probably with truth, that they lose upon the sale of every ton of coal, and that they continue production simply for the sake of finding some employment for the laboring population.

"This paralysis of the chief industry of South Wales has produced already widespread distress, exceeding in intensity and rivaling in extent the misery among the colliers and ironworkers after the strike of 1875. Of the five hundred collieries in Glamorganshire and Monmouthshire, only twenty are working full time. At Cardiff the workhouse is thronged, the board-room and offices have been converted into dormitories, a supplementary stoneyard has been opened for the employment of married men, and the applications for admission are increasing at the rate of about fifty a week.

"As yet nothing quite so bad as the pauperism existing in South Wales colliery districts has been reported from any of the chief centers of the iron trade; but it is certain that the distress in this industry also must become very severe, unless an improvement quickly shows itself, of which at present there are no signs. We published a report from our Birmingham correspondent, in which it was stated that 'several of the works closed lately would remain closed for an indefinite period.' The economical history of 1877 in this branch of trade is

most discouraging. At the beginning of the year there were very sanguine hopes, which might have ripened into reality if the complications in the East had not produced a palsying sense of uncertainty and alarm. Yet the foreign demand for some kinds of iron was diminishing; American competition was threatening; excessive production and accumulation of stocks stimulated a rivalry that caused a general fall in prices. In some districts an attempt had been resolved upon to make a stand against the glutted markets and shrinking values by a systematic limitation of the output. But only partial success has rewarded the effort. The fall in prices has been gradual and general, and is too considerable to be accounted for by certain reductions in the cost of production, as in the price of coal and ironstone and in the wages of furnacemen. This fall, moreover, has gone on in spite of the reduction in the producing facilities of the country. Out of 927 furnaces erected at the beginning of the year only 585 were in blast, and it is probable, we are told, that no more than 500 are now at work. Yet those which continue in blast show an increasing average output, and it is believed that the tendency is toward a smaller number of producing establishments with a larger production from each. The general result, however, is that there is at the same time a reduction in price, a diminution in the producing powers of the British iron industries, and a consequent but not corresponding restriction of the output. Though the war has to some extent interfered with the foreign demand, it is in the home consumption that the depression of which complaint is made is chiefly visible. Stocks have accumulated in nearly every one of the iron districts, even where the new demand for steel rails has attracted business to the detriment of the old iron rail-making mills. The consequence is that the producers of crude iron must in self-defense limit the output, and this can not be accomplished without inflicting many hardships upon a large industrial population."

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A COMPANY has been formed for the construction and working of tramways within the borough of Derby and its vicinity.

## BESSEMER STEEL.

From "London Times."

LESS attention than they deserve has been given to the purely statistical aspects of the Bessemer steel trade. The substitution of Bessemer steel for malleable iron has been accomplished so largely and so rapidly, consequent upon the cheapening of the former product, that people seem to have had regard less to the growth of the steel manufacture than to the decadence of its sister industry, which that growth involved. Nor is this at all surprising considering that statistics of the Bessemer process have not heretofore been very readily accessible. In our own country, for example, there are no official statistics of the steel trade published from year to year to which the public have access. It was not even until a few years ago that the "Mineral Statistics of the United Kingdom," issued from the Mining Record Office, took cognisance of the number of Bessemer steel works established in the country, nor was it until this year that it issued any statistics as to the number of works carrying on the Siemens and Siemens Martin processes, which are now being adopted very largely both in the country and abroad. It yet remains for some official source to collect and circulate the statistics relating to the production and distribution of steel in Great Britain, and we are glad to learn that the British Iron Trade Association has taken this duty in hand. The figures which we shall here make use of will be largely borrowed from the forthcoming annual report of that association on the iron and steel trades during 1877.

The Bessemer process can hardly as yet be said to have passed into the region of history. The incidents of its development are almost of yesterday, less than twenty years having passed since it was practically adopted. Previous to Mr. Bessemer's great invention, steel was chiefly manufactured by the process of Huntsman, who was the first to produce cast steel by fusion in crucibles placed among the coke of an air-furnace. The steel produced by Huntsman's process—which is still carried on to a considerable

extent in Sheffield in the manufacture of mild steel—cost from £40 to £60 per ton, according to the purpose for which it was required. Bessemer, however, produced steel equally suitable for certain ends, by his so-called pneumatic process, at £12 per ton, and, when his royalty had ceased, for considerably less even than this. Successive improvements, introduced since the process was first given to the world, have resulted in making Bessemer steel almost absolutely as cheap, and relatively much cheaper, than ordinary malleable iron. Hence has followed the decay and collapse of the finished-iron trade, which has gone to the wall with startling rapidity during the last four years, involving, as a matter of course, the loss of a great deal of capital and the transfer of much more; the uncertainty, groping, and perplexity incidental to a new industry; the enforced idleness of thousands of workmen, and the creation of new avenues of employment for many more; and, finally, the ultimate economy of all undertakings in respect of which steel has come to be employed.

In this country, which is the cradle of the Bessemer steel trade, as it has been of nearly all other great metallurgical discoveries, the development of this industry has been more rapid during the last five years than during any previous period of equal duration, notwithstanding that this interval embraces such a prolonged and serious tide of adversity. In 1870 there were only eighteen Bessemer steel works in Great Britain, having converters, and the total production of ingots was 215,000 tons. Last year there were twenty-four Bessemer steel works in operation, having 110 converters, and producing about 750,000 tons. Hence the production had more than trebled within seven years. But these figures do not represent anything like the maximum capabilities of the Bessemer plant available for use. The full extent of these capabilities can only be gauged approximately. Bessemer converters, like blast-furnaces, vary in their productiveness according to the treat-

ment they receive. In 1876, according to the *Metallurgical Review* for December, 1877, the average output of a pair of  $5\frac{1}{2}$  to 6 ton vessels in the United States was 225 to 250 tons of ingots per twenty-four hours, and Dr. Siemens was informed that at the North Chicago Steel Works as many as seventy-three blows had been obtained in one pit in twenty-four hours. ("Journal of Iron and Steel Institute," No. 1, 1877). But in this country 180 tons per twenty-four hours from a pair of 7-ton vessels is considered a good yield, and in Germany the average yield of each converter in use did not exceed 6,728 tons per annum—a discrepancy which Dr. Wedding ascribes entirely to the superior mechanical appliances of the American steel-makers (*Reichsanzeiger* for October, 1876). If, however, we assume that each Bessemer converter in the United Kingdom is only capable of yielding ninety tons per twenty-four hours we should have a production of 27,000 tons per converter for 300 working days; and on this average the Bessemer plant already constructed in the United Kingdom should be equal to furnishing 2,970,000 tons of steel ingots per annum—a production equal to that of the whole world at the present time.

On the face of it these figures would indicate that our productive resources have gone far ahead of the demand for Bessemer steel. England is not the steel maker of the world in the sense that she was, until a few years ago, the world's iron maker. We supplied iron to every country in Christendom, because we had learnt, before other countries, how to turn to commercial account the resources with which nature had so liberally endowed us. But before the steel era had been fully introduced other nations had become alive to the importance of supplying their own wants instead of trusting to another, and hence the fact that England's development of the steel trade has proceeded pretty much on all fours with the competitive development of other countries. We have even lost ground relatively, although not absolutely, in the race of development, for the United States have increased their production of Bessemer steel ingots between 1870 and 1871 from 40,000 to 525,996 tons; while England has only

gone from 215,000 to 750,000 tons. Nor is this all. Americans, somehow, get a much better return for the capital invested in Bessemer works than their English competitors. There are only 27 Bessemer converters in the whole of the United States, and yet they produce within 225,000 tons of the yield got in England from 110. The output of Bessemer steel ingots in America during 1877 is believed to have been much larger than in 1876. Her own requirements will supply America with a constantly increasing demand for steel rails. There are now in that country about 80,000 miles of railway. Much of this mileage is single track, but, in the long run, no doubt it will be doubled and supplied with as heavy metals as are used in our own country. To lay the present railroads of America with a double track of rails weighing 70 lbs. to the yard, would require between 15,000,000 and 18,000,000 tons of steel rails, representing at present prices a capital of \$126,000,000. These 18,000,000 tons of rails would require renewal from time to time—for the longest-lived rail must give way at last—to say nothing of the new mileage that must be opened out in the natural order of things, so that the American steel-rail trade may be regarded as pretty safe; and those who have it in hand appear fully determined to exclude, if possible, the competition of this country. But it is not America alone that now offers a rival front. Germany is producing 242,261 tons of Bessemer ingots per annum; France 261,874 tons; Belgium, 71,758 tons; Sweden, 22,789 tons; and even Russia is now entering the field with an annual production of 8500 tons. In Europe and America together there are now 85 Bessemer steel works, with 297 converters, capable of producing, if used in conjunction with the most recent appliances, not less than 7,000,000 tons of steel per annum, or fully three times the quantity actually yielded at the present time.

Although thus obviously suffering from the stagnation that is common to all industries, and most of all to our metallic trades, at the present time, there is a general consensus of opinion that steel is the metal of the future, and that our dependence must more and more be placed upon this product.

Much has been done within the last few years to cheapen the cost of production, so that steel rails at works in Sheffield or Wales cost now within 12s. per ton of iron rails in Cleveland. So much yet remains to be done in this direction that it need excite no surprise should steel rails be ultimately brought quite on a level with iron. But iron seems to be even already doomed. The craft of the puddler and the cunning of the artificer in iron will be more and more at a discount.

Some authorities, indeed, have pronounced puddling to be a thing of the past. This, perhaps, is going too

far, but it is traveling, nevertheless, in the true direction. With due allowances for certain kinds of merchant-iron peculiar to the Staffordshire district, steel will undoubtedly displace iron in the long run. It has done so already for railway purposes. It is fast nearing that point when it will likewise eclipse iron for shipbuilding. The recognition now given to steel for naval construction both by the Board of Trade and Lloyd's Registry will enable it to compete with iron, not only on equal but on better terms, and contracts for the building of both war and merchant vessels are now being executed at several of our ports.

## MOMENTUM.

By DE VOLSON WOOD, C. E., M. A.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

I ACCEPT the corrections by Professor Skinner in the last number of the Magazine, so far as I misunderstood him. But in regard to Momentum, it appears to me that his language is liable to mislead those who have not already fixed opinions in regard to the matter. It is asserted that *Momentum is pressure* "under a certain condition." Granting, for the moment, that this is correct, it gives to the student the idea that *pressure* is the main thing, that it is the *essential* part. The fact is that time, the "certain condition," is an equally important factor. With equal propriety we may assert that "momentum is seconds determined 'under a certain condition.'" For if  $t'$  be the number of seconds during which one pound of pressure must act in order to bring a body to rest, and the other notation as previously used we have

$$Ft = MV = t' \times 1 \text{ lb. of force;}$$

from which  $t'$  may be found when the momentum is known. So that if the force employed be always one pound, the momentum equals *numerically* the number of seconds during which the force must act to produce (or destroy)  $MV$ .

If, in the former case, the time be two seconds instead of one, we have

$$Ft = MV = \frac{1}{2} F'' \times 2 \text{ sec.};$$

and we would then say that momentum is one-half the pressure "under a certain condition."

Momentum is not pressure. It is a result, an effect, produced by pressure upon a free body acting during a certain time. Time and pressure are linked together in the result. One is a factor of the other.

I consider *quantity of motion* as a proper term to express momentum, although, in the light of the difficulties which seem to surround the subject, it may not be the best term. This I explained sufficiently in my former article. If the momentum be expressed by a single letter, as  $Q$ , we have

$$Q = MV.$$

If now  $M=1$ , and  $V=1$ , we have  $Q=1$ , which, say, is a unit of momentum. Simply expressing this operation in common language gives:—A unit of mass moving with a unit of velocity equals a unit of momentum.

All nations and languages must use the same absolute unit for force in the sense that they must not only make the equation

$$F = Mf$$

true, but homogeneous. They may use different units for force, mass and acceleration; but when the preceding equation is established, the second member will be *the absolute unit*.

## MOMENTUM AND VIS VIVA.

By J. J. SKINNER, C. E., Ph. D.

Written for VAN NOSTRAND'S MAGAZINE.

SINCE the last number of this Magazine was published, I have read with mingled satisfaction and chagrin a little book by Prof. J. Clerk Maxwell, entitled *Matter and Motion*. My chagrin came from the thought that in my past ignorance of the existence of this book I had published some things that were here already better presented, and had proposed to introduce into mechanics a word or two for quantities which are here stated to have been already named. My satisfaction arose partly from the poor consolation that I have not yet met with any review in which my lack of knowledge on this last matter has been pointed out, and partly from the pleasure of finding that on some of the questions, whose treatment in our text-books has seemed to me the most faulty, my own ideas are in substantial agreement with those of this distinguished physicist. I wish here to refer briefly to two or three of the author's positions which have a direct bearing on some views that I have lately presented.

1. Although the subject of Prof. Maxwell's book is *Matter and Motion*, I have been unable to find in it the expression *quantity of motion*.

2. The author recognizes the necessity of distinguishing between *momentum* and *toil*; only his word for what I have called *toil* is *impulse*. On page 501 of the last volume of this Magazine, I define *toil* as the *the exertion of force during time*, and say that "the amount of toil of any force will be the product of the number of units of pressure by the number of seconds during which it acts." On page 43 of Prof. Maxwell's book he says, "The product of the time of action of a force into its intensity if it is constant, or its mean intensity if it is variable, is called the *impulse* of the force." I find by reference to his work on the *Theory of Heat* that he has there suggested a similar definition of the word *impulse*, but it had escaped my notice when I proposed the word *toil*. It may be a question, however, whether the common notions of people as to the meaning of *impulse* will not work more or less confusion in attempting to employ it hereafter with this signification. On

page 44 of his recent book, *Matter and Motion*, the author says, "The word *impulse* was originally used to denote the effect of a force of *short duration*, such as that of a hammer striking a nail." I think that this, or something similar, is the meaning assigned to the word *impulse* by most of our books; although within a day or two I have seen in what I believe is our latest elementary work on mechanics, the statement that "An impulse is the *time effect* of a *blow*." But the author of this latter work seems to have been unable to adhere to this conception; for he says a few lines farther on, "When an *effect* is produced in an imperceptibly short time, the *agency which produces it* is sometimes called an *instantaneous force*, . . . sometimes it is called an *impulsive force*, but . . . it appears advisable to use the term *impulse* instead of either of the above," thus imposing on the word *impulse* the meaning of both an *effect* and the *agency which produces it*. The same writer says elsewhere, however, that the word *toil* (proposed as a general expression for precisely what Prof. Maxwell now defines as the *impulse* of a force) "can find no place in mechanics without expelling the present occupant . . . the well-known term *Momentum*." But, although the word *impulse*, according to one of its definitions, as given by the objector to the word *toil*, would seem in many cases to be nothing but a synonym for *momentum*, as also defined by him, yet a real defect in the language of mechanics would be supplied by a general acceptance of Prof. Maxwell's definition of the word *impulse*, provided it could be introduced without the confusion alluded to. Prof. Maxwell, *loc. cit.* goes on to explain that, as there is no essential difference between the case of a hammer striking a nail and any other case of the action of force, the word *impulse* will be used by him as he has defined it, without restricting it to cases in which the action is of an exceptionally transient character. But the quotations from the American book given above would limit *impulse* to either an *effect* of a *blow* or to an *agency* producing an effect in an *imperceptibly*

*short time*; and the liability of continually associating such ideas with the word *impulse* might make it easier and more advantageous for us to attach to the word *toil* the technical meaning that I have proposed, than to give the same meaning to *impulse*, as proposed by Prof. Maxwell.

3. Prof. Maxwell recognizes the advantage of giving an appropriate name to that *unit* of force which, by acting for one second on one pound of matter, shall give it a velocity of one foot per second. I have proposed, on page 422 of the last volume, that this *unit* of force be called a *tend*. On page 42 of Prof. Maxwell's book, he says that this unit of force is called a *poundal*. This word was not mentioned in my copy of his book on *Heat*, but in the last edition of that book he states that it is a name proposed by Prof. James Thomson. It is not alluded to in the comparison of English units with those of the centimeter-gramme-second system, in Prof. Everett's work on *Units*, published in 1875, as revised by Profs. Maxwell and Foster; although the corresponding unit of the C.G.S.

system, called the *dyne*, is there given. If the word *poundal* is established as the name of the unit of force which I proposed to call a *tend*, this word is not admissible, although its brevity would give it an advantage over the word *poundal*.

Any one who wishes to read an elegant presentation of the subjects of matter, motion, force, momentum, vis viva, etc., can find it in the little work of Prof. Maxwell. He assumes for his three fundamental units the *pound* of mass, the *foot* of space, and the *second* of time, and derives the *poundal* of force from these. If this method, as explained by Prof. Maxwell, could be uniformly adopted by all English and American writers, I think it would, on the whole, be more satisfactory than the method in which a *pound* of force (pressure) is taken as a fundamental unit and the unit of mass derived from it, equal to what I proposed to call a *mass*.

It is interesting to observe that Prof. Maxwell's book is one of a series of *Manuals of Elementary Science*, published by the Society for Promoting Christian Knowledge.

## UPON DETERMINATION OF TIME, LATITUDE AND AZIMUTH.

By L. WAGONER, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

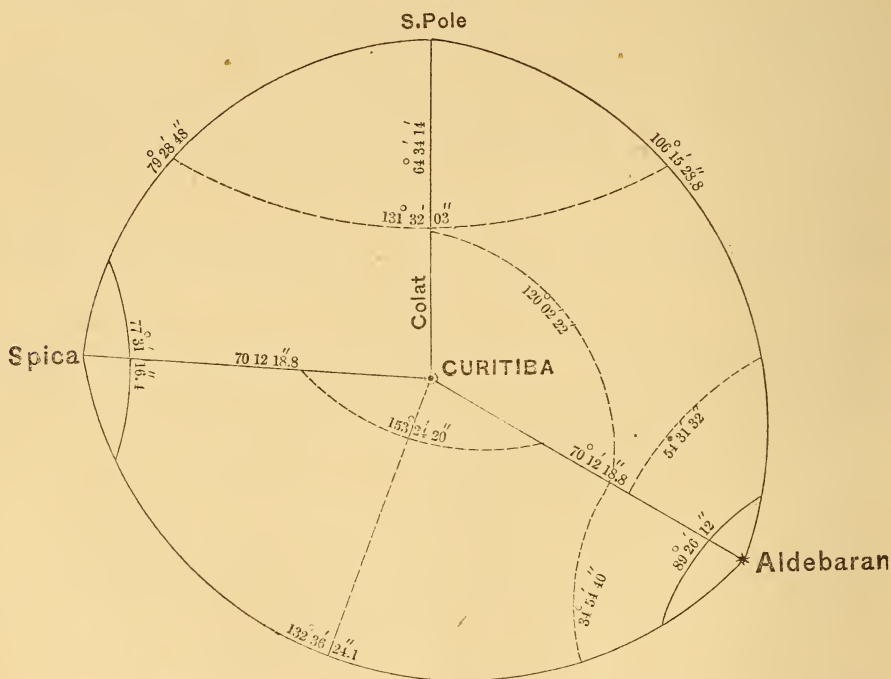
THE object of this paper is to point out a method of determining any or all of the above elements, by means of equal altitudes and the horizontal angle between two stars or planets whose places are known. This method was investigated and first applied while the writer was in charge of the primary triangulation in the survey of the Brazilian empire, and its special feature is that it dispenses with the necessity of the vertical angles, hence an ordinary transit or theodolite capable of measuring the horizontal angle is sufficient. The method adopted is to select two nautical almanac stars, whose elevation differs but little, and whose horizontal difference is from 90° to 180°. The stars should be as low as possible, and for observation with the ordinary field instruments not less than the third magnitude. The instrument having been carefully leveled and the verniers placed at zero, the observer waits until the stars are nearly equal in altitude; the telescope is then clamped fast,

and by means of the lower tangent screw the vertical wire is kept upon the star and its instant of passage upon the horizontal wire is noted; the upper clamp is then loosened and the vertical wire made to cover the second star, and its passage over the horizontal wire is noted upon the watch. The horizontal angle between the two stars is then read off, and, if desired, a mark in azimuth is also observed as well as the magnetic azimuth with respect to the zero, if the instrument carries a needle; this completes the field work, and is usually effected in a few minutes. If the time for observing be well chosen it need not be more than two or three minutes between the passage of the two stars; if the time is longer it may be necessary to introduce a correction for the watch error during the elapsed time.

The reduction of the observation is effected as follows: The first step is to correct the difference of right ascension between the two stars for the interval of

time between the two observations or horizontal passages. In the example given below the watch was known to be running upon mean time, hence no correction is needed for rate. The elapsed time 3M.44s. mean time is converted into sidereal time and is subtracted from the difference of R.A. of the two stars for the following obvious reason. Aldebaran was to the west and was falling, while Spica being in the east was rising, and 3M. 44s. was waited for Spica to attain the same height; hence if the hour angle or difference of R.A. between the two stars had been 3M. 49s. they would both have passed the horizontal wire at the same instant; the difference in R.A. having been corrected we now have the polar angle between the two stars and their polar distances, and resolving the remaining parts of this triangle we have

the distance between the two stars, and the angles at each star between the opposite star and S. Pole. Now one half of the observed horizontal angle is the opposite angle to one half of the distance between the two stars, or, what is the same, we have a right-angled spherical triangle, in which are given the base  $b$  and the opposite angle  $B$ ; the side  $a$  is evidently the zenith distance of the stars or co-altitude, and the angle  $C'$  added or subtracted from the angles at Spica. As Aldebaran will give the angle between observer and the pole, and as the two sides are known the resolution of the remaining parts will give the co-latitude, azimuth and hour angle as time. An example is appended showing the calculation in detail, and it is believed that it will be sufficient to enable almost any one to apply this method:



### EXAMPLE.

*Curitiba, Brazil, Jan. 21, 1877.*

Observation for time, latitude and azimuth, by equal altitude and elapsed time with the horizontal angle between Aldebaran and Spica.

H. M. S.  
8 12 14 P. M. Aldebaran passed H and V wires.  
8 15 58 P. M. Spica " "

3 44 Elapsed mean time=3M 44s.6 sidereal time.

The horizontal angle to right between the two stars was  $153^{\circ} 24' 20''$ , and the magnetic azimuth of Aldebaran was  $242^{\circ} 08' 00''$ .

	H. M. S.
By Nauti'l Almanac AR of Spica was	13 18 44.0
" " " Aldeb. "	4 28 51.2

diff. =	8 49 52 8
Elapsed time	3 44 6

Corrected Polar	} 8H. 46M. 08S.2 }	=C
Angle =		
$\frac{1}{2}C = 65^{\circ} 46' 01''.5$		

## CALCULATION.

To find the distance between the stars :

S. Polar distance	
Aldebaran = 106° 15' 28".8	106° 15' 28".8
S. Polar distance	
Spica + 79 28 48 .0	— 79 28 48 .0
2) 185 44 16 .8	26 46 40 .8
A=92° 52' 08".4	B=13° 23' 20".4
Cot. $\frac{1}{2}$ C 9.6533173	Cot. $\frac{1}{2}$ C=9.6533173
Sin. B 9.3646656	Cos. B 9.9880326
Cosecant A 0.0005447	Secant A 1.3005736
5 57 27.8	83° 28' 44".2
tan. 9.0185276	tan. 0.9419235
83 28 44 2	
89 26 12.0	angle at Aldebaran between Spica and S. Pole.
77 31 16.4	angle at Spica between Aldebaran and S. Pole.
77 31 16.4	sin. comp. 0.0103829
131 32 03	sin. 9.8742269
106 15 23.8	sin. 9.9822761
132 36 24.1	sin. 9.8668859
66 18 12	sin. 9.9617465
76 42 10	sin. 9.9881976
70 12 18.8	sin. 9.973489
76 42 10	tan. 0.6264650
70 12 18.8	cos. 9.5297438
34 54 40	cot. 0.1562088
89 26 12	
2) 54 31 32	angle at Aldebaran between Curitiba and S. Pole.

27 15 46	cot. 0.2879264	cot. 0.2879264
18 01 35	sin. 9.4905974	cos. 9.9781433
88 13 53.8	co. sec. 0.0002069	sec. 1.5106138
30 59 51	tan. 9.7787307	{ tan. 1.7766835 F
89 02 31		{ 89° 02' 31" "
		106 15 28.8
		70 12 18.8
		176 27 47.6
		88 13 53.8
		36 03 10
		18 01 35
120 02 22	Azimuth of Aldebaran from S. Pole.	
58 02 40	Hour angle=3H. 52M. 10s. 7	
70 12 18.8	Sin. comp. 0.0713692	
	Sin. 9.9735489	
54 31 32	Sin. 9.9108241	
25 25 46	Latitude of Curitiba. Cos. 9.9557422	
	H M. S.	
Hour angle	3 52 10.7	to east of Aldebaran.
AR Aldebaran	4 28 51.2	
Sidereal time=	8 21 01.9	P.M.
Observed	8 12 14.0	P.M.
Error of watch	8 47.9	slow on sidereal time.
Comp. of Az.=	239 57 38	
Magnetic Az.=	242 08 00	
Variation E	2 10 22	
Resumé	{	Azimuth = 120° 02' 22"
	{	Latitude 25 25 46
	{	H. M. S.
	{	Sidereal time 8 21 01.9
	{	Variation 2° 10' 22"E

## INTERCEPTION OF RAINFALL FROM SEWERS.

By BALDWIN LATHAM, Mem. Inst. C. E.

A Paper read before the British Association.

THE interception of rainfall from sewers is a subject which has occupied the attention of engineers engaged in the prosecution of sanitary works. It is now generally acknowledged that the admission of large and uncertain volumes of rainfall into sewers at uncertain periods, is attended with considerable difficulties, especially in districts where provision has to be made for the effectual cleansing of the polluted water at the outfall, before it is passed into the ordinary streams of the country.

Hitherto it has been the practice, in the majority of cases where town sewer-

age has been carried out, to admit both rainfall and polluted liquids into one common sewer, and usually storm water overflows are provided at suitable points to relieve the sewers of the excessive burden which they have to carry in time of heavy falls of rain. It must be admitted, having regard to the flushing effect of a sudden storm on a sewer which has been adjusted to carry both sewage and rainfall, that more or less deposit takes place in such sewers, and that the first effect of a storm is to remove the deposit, which passes away with the sewage through the storm

water overflows to the great detriment of the streams receiving the discharges from such overflows. The highly polluted water admitted into the streams through the storm water overflows, although probably only flowing for a limited period of time, produces very serious injury on account of the putrescent state of the solids which have been disturbed in the sewers by the rainfall, and the consequence is that such fluids are more poisonous than ordinary sewage which may arrive at the outfall in a comparatively fresh state.

The complete separation of rainfall from sewers has found its advocates in those who insist, in every case, that the rainfall should flow to the rivers, the sewage to the land. Experience has demonstrated, however, that in towns in which there is considerable traffic, the water flowing from the streets in time of small rainfall is really more polluting, and contains more manurial elements than the sewage proper. This was very clearly shown from a number of samples which were collected from the streets of London, and analyzed by Professor Way. In rural districts, and possibly in some urban districts, a large amount of rainfall may probably with advantage be separately collected and conveyed to the natural outfall of the district, but in the generality of towns the water flowing off the streets, especially shortly after rain commences to fall, is of the worst possible character, and would, if turned into a fresh water stream, seriously pollute it. So long as the first water after rain in populous towns is permitted to flow into the fresh water streams, there must inevitably be a certain amount of pollution. It is therefore advisable that some plan should be adopted in order to obviate the difficulties which beset the authorities of towns on the one hand, and riparian owners on the other. To a great extent, if not entirely, the difficulties attending the admittance of rainfall into sewers has been overcome by the author in a way shortly to be described.

It may be very correctly assumed that if the whole of the rainfall of a district could be passed into a system of sewers, in the course of one year it would about equal the total volume of ordinary sewage produced by an average

population inhabiting a town district which has an abundant water supply. Taking a district in which there are fifty persons to the acre, with a rainfall of twenty-five inches, each person contributing five cubic feet of sewage per day, the annual rainfall, if it could be all conveyed to the sewers, would about equal the total annual volume of the sewage. However, we know from experience that it is but a very small quantity of the whole rainfall in town districts which finds its way to the sewers. The smaller falls have at certain periods no appreciable effect on the sewers, the larger falls rarely contributing, under the most favorable circumstances, more than seventy per cent. of their volumes to the sewers. If the rain were uniformly distributed, there would be little or no difficulty in admitting it into the sewers, but unfortunately the rain has to be conveyed away as fast as it falls, and provision has to be made in the sewers for a very much larger quantity than anything approaching the daily average proportion of the annual rainfall. In the case of London, where provision is made for carrying only a  $\frac{1}{4}$  inch of rainfall in twenty-four hours in the sewers, after allowing for the fluctuating flow of the sewage, the capacity for rainfall in the sewers is equal to two-thirds of the total capacity of the sewers. These proportions show the importance of the subject, and by no means exaggerate the difficulties at the outfall.

The author has recently introduced a system of intercepting the rainfall from sewers, which obviates many of the difficulties arising in towns having to contend with large volumes of rainfall in the sewers, and at the same time the method adopted tends to preserve, to a very considerable extent—even in the case of crowded towns—the purity of adjacent streams. This plan has been put into practical operation in the borough of Longton and in the contiguous district of the East Vale Local Board. These combined districts contain a population of about 25,000 persons occupying an area of about 986 acres. The whole district has recently been sewered under the author's directions, and arrangements have been made with his Grace the Duke of Sutherland, the adjoining landed proprietor, by which

the sewage of the town is conveyed to his Grace's property, there to be utilized in irrigating land. It was a stipulation, however, on the part of the Duke of Sutherland, that as far as possible the rainfall should be intercepted from the sewers. With this view, the author introduced a number of what are called "Rainfall Interceptors," or an arrangement by which large or impure rainfalls are intercepted from the sewers, while the small rainfalls, which in this particular district are remarkably impure, pass into the sewers. It should be observed that in this district a part of the sewage passes down the street gutters, owing to the fact that many of the houses are built back to back, and have no other ready means of disposing of the slops, except by throwing them into the streets. It is obvious, therefore, if a separate system of sewers alone had been constructed in such a district as this, one set for sewage proper, and the other for rainfall, that the rainfall sewers would necessarily discharge into the adjoining stream a large part of the sewage; and in time of small rainfall, the water flowing from the streets, owing to the character of the material used for repairs, and the great traffic over them, would further tend to pollute these streams. Before commencing a new system of sewerage, it was found, as is generally the case in most towns, that there already existed a number of sewers which were, however, of such an imperfect character as to be insufficient for dealing with the sewage proper, but might be improved and retained for surface water. All these original sewers have been retained, improved, and extended so as to embrace the whole area of the district, there being virtually two systems of sewers in the district; the new sewers are used for conveying the sewage proper, and the old system of sewers has been extended, and is used for collecting the rainfall, and, necessarily, part of the sewage of the district. Up to this point in the arrangement there is nothing new. The improvements and novelty, however, consist in making a connection between the rainfall sewers and the sewers proper. At suitable points what is termed an "interceptor" is introduced, which consists of a leaping weir so arranged that when

there is a small quantity of water flowing down the rainfall sewers, and the liquid as a natural consequence is very much polluted, it passes through an adjustable opening into the sewer proper, but in time of rainfall it is only the first and most impure water which passes by the opening into the sewers, for so soon as the volume of the rainfall increases, so as to increase the depth of water flowing in the rainfall sewer, an increase of velocity takes place, and this increased velocity enables the large and purer rainfall to leap over the opening provided into the sewer proper, and so the rainfall passes away to the natural streams of the district. The principle is similar to that first adopted by Mr. J. F. Bateman, C.E., F.R.S., in the Manchester Waterworks, for the separation of clear and other water. This system has now been in operation in Longton for some time past, and gives the most perfect satisfaction to the authorities of that thriving manufacturing town. The total cost of the works of sewerage at Longton and East Vale, consisting of a new system of sewers for the whole of the district, a distinct surface water system, provision for manholes, gulleys, ventilation, and engineering and superintendence of works was £35,060. Of this amount £5500 have been expended upon the surface water system and the rainfall interceptors. Twenty-two of these "rainfall interceptors" have been constructed in the district at an average cost of £31 each. The opening between the interceptor and the sewer is adjustable, or may be entirely closed, but when once the opening is adjusted the apparatus is entirely self-acting.

It should be mentioned, in reference to these "rainfall interceptors," that in cases in which the channel into which the rainfall is discharged is liable to be flooded, in order to prevent the floods passing back through the openings into the sewers, a special arrangement of valves was introduced, so that any rise of water in the rainfall outfall would close the openings between the rainfall sewer and the sewer proper.

In the report of the Warden of the Standards the Russian archine was given as of 20 in. English. In a later copy of the report this is corrected to 28 in.

## THE MINNEAPOLIS SUSPENSION BRIDGE.

By THOMAS M. GRIFFITH, Civil Engineer.

Written for VAN NOSTRAND'S MAGAZINE.

THE first bridge which spanned the Mississippi River was a wire suspension, of 620 feet, which was opened to the public, on the 23rd day of January, 1855, with the most imposing ceremony the then infant town of St. Anthony and the Territory of Minnesota could command.

The new settlement was justly proud of its achievement, and as a hastily extemporised pageant glided at full gallop over the snow covered rolling prairie, (so soon to teem with the industry of a city), amid the jingle of sleigh bells, which in their numbers, vied supremacy over the discordant clang of a recently organized frontier band; and with the National colors borne aloft, from hill to hill, unfurled to full length in the dazzling sunlight by the Northern breeze, the generous enthusiasm of the occasion, gave vent to praises loud and long in honor of the bold projectors of the enterprise, and of those who had been mainly instrumental in its success.

The structure was located about an eighth of a mile above the falls of the Mississippi, and connected the west bank of the river with Nicolett Island; the crossing from which to the eastern bank, was made upon a rude pile bridge, which had been in use for some time, in connection with a wire rope ferry, for which a charter had been granted by an Act of the Territorial Legislature, Feb. 19th, 1851.

This enterprise was expected to draw the trade of the settlers of the west side; and as capital, as well as business, was limited, the bridge was proportionately light in design. But it was hoped, and it really proved itself, to be fully up to the requirements of a frontier settlement, and cost but little more than \$40,000.

The floor beams were of white pine,  $3\frac{1}{2}$  inches by 14 inches, placed 3 feet and 9 inches apart from center to center, upon which light stringers were laid to support the floor plank. The width between the trusses was 17 feet. This platform was supported from the cables

by suspenders, made of eight rounds of No. 10 wire formed into a skein; the upper end or "bite" of which passed over a cast iron yoke, which embraced the two cables on either side. The lower end or "bite," with a small casting interposed, supported either end of the floor beams. The four cables contained in all 2,000 strands of No. 10 hard drawn charcoal iron wire, made by Messrs. Cooper & Hewitt. These cables were formed of skeins of 124 and 126 strands, which were "laid up" on the Island, and moved and raised to their positions on the towers, which were strong frames of white pine timber, consisting each of 16 posts, 12 inches by 12 inches,—so arranged, that at each corner of a frustum of a right pyramid, with a square base of 14 feet by 14 feet, there were four respectively, but separated each from each by a space sufficient for the ventilation of the timber, and the passage of the tie bolts necessary to hold them together, and up to the system of inter-bracing.

These posts were capped with three courses of white oak timber, the direction of the grain being reversed in each tier, and the whole trenailed through and through. Castings rested upon these, and between them, and similar ones, attached to timber saddles, "six pounder" cannon balls were interposed.

The anchorage was obtained by working eight holes, eight inches wide and three feet long, through the lime stone rock which is ten feet in thickness, and of nearly horizontal stratification; and underneath which lies the white sand.

Through these holes the link bars of the anchorage chains were thrust and secured to cast iron plates of about 1500 lbs. each, which were taken into their positions underneath the ledge, through tunnels driven into the easily excavated sand. Thus a very secure anchorage was obtained, at a comparatively small cost.

The weight of the whole of the suspended material, exclusive of the No. 10 wire of the cables was  $91\frac{6.5}{100}$  tons. The

vertical deflection of the cables was 47 feet, and the horizontal inward deflection or "cradling" was 10 feet.

It is evident that so light a structure was only admissible under those peculiar circumstances which gave birth to the enterprise; and which were soon to be subjected to the caprice of those fluctuating courses and channels, which the sagacity of trade is always seeking and endeavoring to establish.

The farm of the first brave and indomitable settler, on the site of the future city, soon became too valuable for agricultural purposes. Traders established themselves, in and among his graneries. Manufacturers invaded his corn and wheat fields, and ere long terms annexation were almost dictated to

the first business center, as if to a patronized suburb, and the bridge which was to have swelled the coffers of the pioneer mercantile adventurers, was the means of depleting them. The current of trade over the bridge was reversed, and with time increased to such an extent, that the structure could no longer conveniently or safely supply the demands made upon it, and the city determined to erect another upon the same site, more suited to the new condition of things. This was commenced in the spring of 1875, 21 years after ground was broken for the foundations of the first structure; and it was completed in the spring of 1877, a little more than two years having been consumed in its erection, and at a cost of about \$175,000.



The old bridge had for several years been subjected to a much heavier traffic than was contemplated by its projectors; still, upon taking it down to give place to the new one, the wire of the cables, except in places upon which dirt had been allowed to accumulate, so as to form (literally) hanging gardens, no deterioration was apparent upon mere inspection. Samples of the wire is now in the hands of the manufacturers for examination and test.

The span of the new bridge is  $675\frac{1}{10}$  feet, and the length of the platform is 670 feet, and it has a camber of four feet at mean temperature. The floor beams are of white pine timber,  $3\frac{1}{2}$  inches thick by  $13\frac{1}{2}$  inches in depth, and 36 feet in length, placed together in pairs, but

separated each from each by a space of one inch, and which from center to center are a little less than five feet apart. The beams support stringers and plank-ing, upon which street car rails and wooden block paving is laid. The platform is attached to the two main cables, containing each 3648 strands of No. 9 iron wire, by suspenders of 24 strands of the same, and inch round iron rods; and to two light cables of 450 strands each, (which aided materially in the process of construction) by wire suspenders of 16 strands, and  $\frac{3}{4}$  inch round iron rods—the rods being introduced where the lengths are less than 12 feet. At mean temperature the vertical deflection of the main cable is 58 feet, and the horizontal inward deflection or "crad-

ling" is  $6\frac{25}{100}$  feet. The light cables deflect vertically 58.33 feet, and horizontally and inwardly  $\frac{92}{100}$  feet, or the static resultant of the tangents to the curves at the points of suspension, make with lines parallel to the directrices of the curves, a vertical angle of  $18^{\circ} 58' 48''$ , and a horizontal angle of  $1^{\circ} 45' 32''$ , and a coefficient of tension of 3,0784.

The wire weighing 17.95 feet to the pound, with an average ultimate tension of 1507 lbs., the supporting capacity of each (half) strand is equal to

$$\frac{[1507 - \sqrt{377.557^2 + 4 \times (58.04^2 + 462^2)}] \times 3.0784 \times 3}{17.95} = 1384 \text{ lbs.}$$

The platform, and all of the suspended material, exclusive of the No. 9 wire of the cables, and the floor stays weigh 659508 pounds, and the surface of the platform, available for a moving load, is 17390 superficial feet. If therefore  $x$  = the number of pounds which may with safety be permitted as a moving load upon the platform, per square foot of surface,

$$\frac{17390}{2} \times x \times 3.0784 \times 5 + \frac{659580}{2} \times$$

$3.0784 \times 3 = 7296$  = the number of strands of No. 9 wire in the cable, and  $x = 52.9$  lbs.

The cables rest upon cast iron saddles which have a movement, by means of rollers, upon plates bedded upon the masonry of the towers, which from the foundations to the top-finish are 111 feet in height, and at the height of roadway they are  $13' 3'' \times 13' 6''$ . The pair on either bank are 35 feet apart, from center to center, and from the opposite banks of the river, 675.1 from center to center. The clear width of the space between the towers on either side is 20 feet, the same as that of the distance between the main trusses. (Pedestrians pass around the towers in order to reach or leave the pathways of the platform.) They are built of limestone quarried in the immediate vicinity, and are coped and trimmed with a superior quality of granite, obtained from quarries some 90 miles further up the river.

The anchorage is similar to that of the old bridge. Holes 12 inches by 48 inches were slotted through the limestone, and the cast iron anchor plates, each weighing some five tons, were moved into their positions through tunnels driven into the sand from shafts sunk midway between the anchorages. The link bars were passed through the holes, and the pins securing them to the castings put in place, and their alignment and adjustment insured by means of an instrument devised for the purpose. A mass of masonry is built upon the top of the rock in which the anchorage chain of link bars rests and are deflected to their proper positions. The masonry serves also as retaining walls, and the upper portion being casemated, affords a convenient office for the bridge police, and for the storage of tools, &c. All of the iron of the anchorage, both cast and wrought, as well as the wire ends of the cables, were enclosed in concrete (or what purported to be that material, and by great courtesy might be considered to be such) in the same manner as that of the Niagara Railroad Suspension Bridge. Late investigations into the condition of which, by competent and careful engineers, has given rise to the suspicion that that treatment of the cable end, even when done in the best possible manner (and not by contract) is not well adapted for the purpose of protecting them from rust. There is reason therefore to apprehend that in cases where homœopathic doses of cement are mixed with allopathic potions of water and sand, and the mixture poured into the tortuous interstices of a pile of stones, that similar investigations would be in order at no distant day. All persons whom this may concern are respectfully advised by the engineer to examine into the proceedings of the City Council in relation to matters pertinent thereto.

The arrangement for stiffening the platform and reducing its vibratory motions are: First, four trusses of the Howe type, two of them seven feet in depth, and located outside of the carriage way and street car tracks, and two of them six feet in depth located outside of the foot paths.

Secondly, four floor stays on each quarter which, being attached to an independent saddle on the tower, are held by

a single stay of strength equal to the resultant of the four, which is also attached to the saddle, and carries the strain down to the anchorage. At the point of attachment of each of the floor stays with the platform a spruce timber spar is so placed as to thrust upward, in a direction normal to the curve of the cable, and light cross cables attached to the main cables on either side and adjacent to the contract of the spars with them, and drawing them toward each other a little more than is due to the static effect of the weight of the platform.

The ends of the lower chord of the main truss is enlarged by the addition of timber, and shod with a cast iron plate, between which and another having a bearing against the masonry of the tower, a sheet of rubber is placed, which arrangement, while it holds the quarter firmly as rolling loads, or the force of winds act alternately upon the four stays, admits however of a motion, meeting with an increasing resistance through a short space.

And thirdly, fastening the middle portion of the cable, for a distance of 70 feet, to the platform, by means of cast iron "cradled" bearing blocks and clip bolts.

These combinations appear to give satisfactory results. The platform is, the weight of suspended material, the span and deflection considered, very free from the usual vibratory motions of this

kind of structure. And any additional strain which they involve, is more than compensated for by the sixteen floor stays, which have not entered into the estimate of the strength of the bridge.

In case the bridge should be subjected to such storms as have proved destructive to suspension bridges, these timber spars will probably prevent the rupture of the suspending rods at those points where they are the first to be subjected to those shocks and jerks, which are caused by the want of uniformity of the vertical motions of the cable and platform, which takes place when a certain degree of violence has been attained.

Twenty of these storm spars were introduced into the old bridge which, probably on account of this improvement, withstood some violent storms which might have otherwise been disastrous, and the guy lines to it having but little downward pull, were attached to the cables at the point of connection of the spars as well as to the platform, which insured a vertical motion of both.

In design the new structure is nearly what the engineer intended it to be. In workmanship also it is as nearly so as a demoralizing conflict with some of the vile annual distillments of ward politics could permit us to reasonably hope for, although not up to the standard desirable in such works.

## THE SUBJUGATION OF THE GASES.

From "Iron."

THE autonomy of the once permanent gases is over. Oxygen had already fallen before the gas-compelling M. Pictet, of Geneva, and the equally gas-compelling M. Cailletet, of Châtillon-sur-Seine. The latter, however, has established himself as a very prince of the power of the air, by his conquest of nitrogen, hydrogen, and the mixture of oxygen and nitrogen inspired by our lungs. These stubborn gases have yielded at length to cold, pressure, and M. Cailletet's mandate of Condense and

Liquefy. Should our readers ever be tempted to think of the phrase "airy Frenchman," we hope they will couple with it the remembrance of the remarkable form just given to the airy nothings of oxygen, nitrogen and hydrogen by the brilliant physicists whose names re-echo in our pages.

This splendid conquest enlarges the reign of law magnificently. How it was effected our readers will be prepared to learn from our last week's account of the coercion of oxygen. We gave the

first place in that account to M. Pictet; in the following we give it to his rival, whose words we quote:

"I have been following up my experiments on the liquefaction of gases, and I am happy to announce to the Academy that I have succeeded in liquefying nitrogen and atmospheric air. Hydrogen itself furnishes some indications of liquefaction, as I shall presently show, meanwhile I give a few details concerning my experiments:

"*Nitrogen*—Pure and dry nitrogen, compressed at about 200 atmospheres at  $+30^{\circ}$ , and then suddenly expanded, is completely condensed. First of all appears a substance looking like a pulverised liquid, in little drops of appreciable volume; then this liquid disappears little by little, from the walls towards the centre of the tube, forming at last a sort of vertical column, the axis of which follows the axis of the tube itself. The total duration of the phenomenon is about three seconds. These appearances leave no doubt whatever as to the true character of the phenomenon. I first made the experiment at home, at a temperature of  $-29^{\circ}$ , and repeated it a large number of times in the course of yesterday, December 30th, in the laboratory of the Ecole Normale, in the presence of many scientific men, among whom were several members of the Academy. The venerated M. Boussingault, whose name I am permitted to mention, was one of the latter.

"*Hydrogen*.—This gas has always been looked upon as the most refractory of gases, on account of its low density and the almost complete conformity of its mechanical properties to those of perfect gases. It was therefore with very little confidence as to results that I decided on subjecting it to the treatment which determined liquefaction in all other gases. In my first attempts I failed to perceive anything noticeable; but, as is frequently the case in experimental science, a long habit of observing phenomena gives, by and by, the ability to recognize their signs under conditions which at first obscured them. So it was with hydrogen. Repeating my experiments this very day, before MM. Berthelot, H. Sainte-Claire Deville and Mascart—whose witness I am allowed to appeal to—I succeeded in observing signs of

hydrogen liquefaction in conditions of evidence which did not appear doubtful to any of the men of science who saw the experiments. The latter was repeated a large number of times. When operating with pure hydrogen, compressed at about 280 atmospheres, and then suddenly expanded, we saw formed an excessively fine and delicate mist, suspended the whole length of the gas, and suddenly disappearing. In spite of its extreme attenuation, the production of the mist itself was considered to be beyond doubt by the scientific observers who watched my experiments to-day. And they had it repeated several times in order to leave no doubt as to its reality uncleared.

"*Air*.—The liquefaction of air is *de facto* demonstrated by that of nitrogen and oxygen. Still, it was very natural to make the liquefaction of air the subject of a direct experiment. As might have been expected, this was completely successful. I need hardly say that the air had been dried beforehand, and freed from carbonic acid. Thus has been confirmed the exactitude of the reasoning of the father of modern chemistry, Lavoisier, as to the possibility of reducing air to a liquid form, producing thereby matters possessed of new and unknown properties.

"In closing this letter to the Academy, let me express my thanks to M. Berthelot, and my beloved master, M. H. Sainte-Claire Deville, for their hearty sympathy and the hospitality with which I have always been received at the laboratory of the Ecole Normale."

This communication of M. Cailletet's was read at the usual Monday meeting of the Academy on the 31st ult., before an audience which felt, if we may borrow Milton's splendid phrase, as if another morn had risen on mid-day. Following on the communication from M. Cailletet, was read the following "Vidi" from M. Berthelot.

"M. Berthelot begs to say that he witnessed the experiments conducted by M. Cailletet, yesterday and to-day, on nitrogen and hydrogen. The liquefaction of nitrogen seems to leave no room for uncertainty after the succession of the phenomena which have been described.

"The observations made on hydrogen

yielded signs of liquefaction which, to his eyes, were not doubtful. They were, however, less complete and more difficult to appreciate than in the case of nitrogen. From their appearance, and the brevity of their duration, they may be compared with the attenuated liquid dust produced towards the end of the phenomena recognized with nitrogen, at the moment when the cloud is vanishing. The extreme tenuity of the liquefied particles constituting this hydrogen mist—a sort of diffused luminosity—as well as their more rapid return to the gaseous condition, accorded entirely with the comparative properties of hydrogen and the other gases.

“That which characterizes M. Cailletet’s experiments, and gives them the certitude which belongs to them, is the fact that, in one and the same transparent and limited space, they permit the comparison of the gas in the three successive conditions of a compressed elastic fluid, a pulverized liquid, and a fluid in great part expanded. We must also take into account, in estimating the value of M. Cailletet’s experiments, the facility with which each can at once be repeated as often as may be desired, so that each phase of the phenomenon can be reproduced for separate study.

“More, in such a matter, cannot be demonstrated; at least, not until some scientific man, profiting by the recent discoveries, succeeds in isolating in the static condition of stable liquids, capable of being kept permanently under observation, the gases which have been liquefied for the first time by M. Cailletet in a dynamic state, if I may be allowed the expression—that is, in the state of liquids which, momentarily formed under the observer’s eye, at once evaporate and escape observation.”

While M. Cailletet has been bringing hydrogen and nitrogen into unwilling bondage, M. Pictet has been completing his triumph over oxygen. The *Journal de Genève* of the 29th ult. gives us the following details of his fourth experiment:—

“On the evening of the 27th, M. Raoul Pictet repeated for the fourth time his experiment of the liquefaction of oxygen. At 10 o’clock exactly the pressure gauge, which had gone up to 560 atmospheres, fell in a few minutes to 505, and remain-

ed at this figure for more than half an hour, indicating thereby the passage of a part of the gas in the liquid state, under the influence of 140 degrees of cold to which it was subjected. The tap closing the orifice of the tube was then opened, and a jet of oxygen escaped with extraordinary violence. A ray of electric light was thrown upon the conical outflow, and showed that the jet was principally composed of two distinct parts—a central part a few centimetres long, the white color of which indicated the presence of liquid, or, perhaps, solid elements; the other an exterior part, the blue tinge of which indicated the return of the compressed and frozen oxygen to the gaseous condition.”

Allusion has been made above to the accuracy of Lavoisier’s previsions as to the non-permanence of the gases. The session of the Academy on the 24th ult. was thought fully prepared by M. Dumas for the reception of the intelligence by which it was then startled. Before reading the communications which we laid in full before our readers last week, he read out a passage from Lavoisier’s work, in which the following sentences occur:—“Were the earth suddenly transported to the cold regions, say of Jupiter and Saturn, the water which now forms our rivers and seas, and probably the greater number of liquids we are acquainted with, would be transformed into solid mountains. . . . The air, or, at least, a part of the aeriform substances which compose it, would, beyond doubt, cease to exist in the state of an invisible fluid, and this change would produce new liquids of which we have no idea.”

M. Berthelot has already found in a circumstance attending M. Pictet’s experiment, support for opinions of his own in mechanical chemistry, the acceptance of which has hitherto been found difficult for want of direct proof. He draws attention to the fact that the decomposition of the potash chlorate into oxygen and potassium chloride, an exothermic reaction, not limited by its inverse, is not put a stop to by a pressure of 320 atmospheres. It is probable that the rapidity of the reaction is altered, as well as perhaps the temperature at which it is effected; but the reaction itself does not fail to take place.

In the present and in our two preced-

ing issues, our readers have had laid before them the fullest details of the achievement, the glory of which we may fairly envy our neighbors across the Channel. There now remains only to reproduce the discussion at the Academy on the 24th as to the priority in success of M. Pictet and M. Cailletet. Our readers will be aware that both these gentlemen are engaged in industrial pursuits, the former being well known as a maker of refrigerating apparatus, and the latter as the owner of large ironworks. The great truth which has been revealed to both did not, however, find them quite babes and sucklings in science, M. Pictet's researches in cold having already won considerable notice, M. Cailletet being already an authority on the cognate subject of heat. The official report of the discussion proceeds to say :—

M. H. Sainte-Claire Deville.—M. Cailletet repeated his experiments on the condensation of oxygen in the laboratory of the Ecole Normale on Sunday, December 16th; their success was complete. If the account of them (dated December 2d) was not published till to-day (the 24th December), the reason was that M. Cailletet was a candidate for the place of correspondent given him by the Academy in its sitting on December 17th; that he did not care to put in on the 10th, when his testimonials were being examined, scientific work, the results of which had not been confirmed by experiment conducted in the presence of competent witnesses. And on the 17th, the day of his election, he did not think it fitting to publish a fact, important, it is true, but undiscussed in the secret committee of the 10th. Fortunately, however, I had taken the precaution, on the 30th, of sealing and having signed by our perpetual secretary the letter containing both the news of his discovery, and the confidential expression of the honorable sentiment by which he was then guided. The priority therefore belongs to him unquestionably. But I ought to say that M. Raoul Pictet's remarkable operations are not in the slightest degree discredited thereby. His *modus operandi* is altogether different from that of M. Cailletet. The freezing process founded on the expansion of a gas or a vapor, a principle which had not hitherto been applied, and M. Cailletet's simple apparatus, indicate

instructive experimentation in future researches. It is ten years since, to my own knowledge, that M. Cailletet began to lay the foundations of his present experiments. Being desirous of obtaining, under all circumstances, precise and rigorously-measured results, he prepared, at the cost of long labor, the free air-pressure gauges, the description of which has been published in our *Comptes rendus*, and has carefully studied the thermometric apparatus due to M. Regnault and M. Berthelot. It is therefore with a well-founded repugnance that he now speaks of pressures determined by metallic manometers, and temperatures given by alcohol thermometers. But for his anxiety as to the strict accuracy with which he wished the results of his experiments to appear, he would long since have brought to proof the important facts observed and published by him with regard to gases, particularly the binoxide of nitrogen, carbonic oxide and oxygen.

M. Jamin regarded the possibility of liquefying or solidifying oxygen as now demonstrated. One experiment is as good as the other. M. Pictet's adds little to M. Cailletet's, since (although the former gentleman was the first to state that he had seen oxygen precipitating itself in a liquid form) the mist perceived by M. Cailletet at the moment of expansion shows that the oxygen had ceased to be transparent, *i.e.*, gaseous, and that it had become a solid or a liquid. To have seen the liquid or the mist without having been able to collect either, is one and the same thing. The final experiment is yet to be made; it will consist in keeping oxygen liquid at the temperature at which it boils, as is done with the protoxide of nitrogen, or in the solid state, like carbonic acid, being preserved in this condition by reason of the enormous latent heat required for gasification. Everything gives ground for hoping that the two able experimenters will, each from his own side, approach each other and meet in this final result.

M. Dumas, after what had been said, considered that the independence of the researches of the two gentlemen in question had been fully established. Pursuing the same object, creating methods and appliances which cannot be improvised, each had arrived by his own road at the same result, neither having any

knowledge of his rival's labors. The fact is frequent in the history of the sciences.

M. Regnault informed the Academy that he was present, five years since, at the first preliminary experiments made at Geneva by M. R. Pictet and M. De la Rive, with a view to obtain the liquefaction of gases. He had been struck by the remarkable ingenuity of the apparatus.

M. Berthelot, while admitting the originality of M. Pictet's experiments, observes that the experiments conducted by M. Cailletet on the liquefaction of oxygen are the necessary and foreseen result of the researches of the latter gentleman on the liquefaction of the binoxide of nitrogen, published in the *Comptes rendus* for November 26th, itself a sequel of the liquefaction of acetylene (reported on November 5th). His experiment on the liquefaction of oxygen during expansion was made on December 16th at the laboratory of the Ecole Normale, before several members of the Institute and other scientific gentlemen, under the amplest conditions of publicity, just a week ago. We cannot, pursued M. Berthelot, refuse to acknowledge the importance of the logical order of the series of experiments above detailed, which have been spread over a

period of a couple of months, and have recalled the attention of our learned men to a problem which remained in suspense many years on account of practical difficulties apparently insurmountable. After being the first to show, in an unexpected manner, how probable the solution of this problem was becoming in the hands of experimenters provided with sufficient means for carrying out their experiments, M. Cailletet has been his own first follower, by reducing the greater number of the gases hitherto deemed incoercible, namely, the binoxide of nitrogen, marsh gas, carbonic oxide, and oxygen.

What may follow on the occupation of this new ground, we are not prophetic enough to be able to say. We may repeat with M. Jamin that the coerced gases, though subjugated, are still to be regarded as more or less prisoners at large, until they have been incarcerated within walls of frost, and held in the permanent bondage of stable solidity. But we may point out that not only have M. Berthelot's theories received an unexpected support, but that our old friend the "absolute zero" has been cut loose from his moorings at  $-273^{\circ}$ , and is drifting out probably into the interstellar spaces. Where will he settle?

## A NEW FORM OF PITOT'S TUBE FOR GAUGING STREAMS.

By S. W. ROBINSON, Professor of Mechanical Engineering in the Illinois Industrial University.

Written for VAN NOSTRAND'S MAGAZINE.

### PREVIOUS FORM.

The most elaborated and convenient form of Pitot's tube for measuring the velocity of running water, which has come under the notice of the writer in any published work, is that devised by M. Darcy, a French *hydraulician* of much note, who has enriched hydraulic science with material of great value.

The instrument, as thus improved by Darcy, is illustrated and described at length in Morin's *Hydraulique*, p. 133.

As described by Morin, the instrument, altogether, is about six feet in length. About two thirds of the total length is occupied by two parallel glass

tubes and a scale. These are for the purpose of reading the heights of the water columns. The tubes are extended to the lower end of the instrument by small pipes, which then turn and run at right angles to a distance of a few inches. The extreme ends are attached to each other just as shown in Fig. 3, to be afterwards explained. The upper ends of the glass tubes communicate with each other by a fitting which has a branch outlet and a stop cock, so arranged that the air may be more or less exhausted from the tubes. Near the bottom of the glass tubes is a second cock by which both tubes may be

stopped or opened at pleasure. These parts form a single portable device.

To use the instrument in measuring a velocity, the lower end is immersed, headed up stream, the water drawn up in the tubes to a convenient point on the scale\*, and the reading taken of the difference of height of water columns. For streams of greater depth than the length of instrument, the latter is attached to a rod, and sunk to any desired point. When it is supposed that the columns are ready for reading, the cock at the bottom of the glass tubes is closed by means of a cord extending to the surface, by which the columns become fixed. Then the instrument may be raised and the reading taken.

This instrument has been thus briefly described in order that the peculiarities of the new form may be more clearly perceived.

#### FEATURES DESIRED IN A PITOT'S TUBE.

Any one who may attempt to measure the velocity of a stream by means of a Pitot's tube, will experience an annoyance from the oscillating of the columns. This may, however, be much reduced by making the passage in the tubes small at some point, though appreciable oscillations still remain. To blindly fix the columns while in such a state of oscillation, without any means of knowing where they were in the range of disturbance must prove very unsatisfactory; as much so as a reading, caught "on the jump," by a mere glance at the scale if under the eye of the observer. Nevertheless, such a reading is the exact equivalent of one taken with the instrument submerged, as contemplated in the use of Darcy's form of it, for streams deeper than six feet. A device by which the scale may always be read, deliberately, at the surface, the instrument being still in action, will evidently be an improvement as regards the confidence which can be placed in the result of a certain number of observations.

Again when the cock must be closed, the instrument raised, the reading taken, the instrument lowered and the cock opened for each observation, it is evident that the possible number of readings which can be taken in a day will fall

very far short of that which could be obtained from the scale if placed constantly in a convenient fixed position at the surface. For instance, one reading in from three to five minutes might be regarded as reasonably rapid with the Darcy instrument, while under the other condition, they could be taken as often as once in 8 or 10 seconds, or say 20 times as fast. The importance of this hastening in the rate of progress is at once apparent from the fact that it is generally desired to know the quantity flowing in a stream at a given hour or day, and not at a certain week or month during which period the rise or fall may render the result entirely unsatisfactory, if not useless.

#### MAIN FEATURES OF THE NEW FORM.

The modification of Pitot's tube, forming the subject of this article, contemplates securing all the advantages hinted at above. To produce this modification, it is only necessary to separate the Darcy instrument at the bottom of the scale and glass tubes, connect the two parts by small rubber hose of any desired length, so that the scale may remain stationary in a boat while the other portion which carries the tips of the tubes may be placed, at the pleasure of the operator, at any point between the surface and bottom of stream. In one sense the instrument is still the same, it being only lengthened, the length in the Darcy form being an arbitrary matter. Indeed, the change is so simple, and results in an improvement so important as regards convenience of application, rapidity of work and precision in results, that it seems due from those who may have used the instrument, that they should have devised, adopted and described this modification previously. If this has been done, the limited facilities of the writer for searching out such fact, must be offered as the apology for the present article.

#### ACTUAL TRIAL OF THE NEW FORM.

This new form has already been put to practical test in gauging the Sangamon, a small river in Illinois, by Mr. William Buckingham who made it the subject matter of his graduating thesis, class of '77, School of Mechanical Engineering of this University. The construction of the instrument used in this

\* An indefinite number of readings may be taken after once filling the tubes.

instance was somewhat rude, though it served its purpose admirably. The extremities of the tubes placed in the stream for the current to act upon, and serving as the lower portion of the instrument, were of glass, about ten inches long, and drawn down to an opening of about  $\frac{1}{32}$  of an inch at the up stream ends. These were attached to a slide which held them horizontal and parallel; one being straight for the entire length, while the other was turned at right angles about half an inch from the tip end. The slide was fitted to play on a square rod, the latter in use being set vertical; and so oriented that the tubes headed up stream. Then the straight tube received the current at its open end by direct impact, while the bent one was indifferent to the current, the lip being at right angles. These tubes were of glass simply because convenient. Rubber hose, some less than  $\frac{1}{8}$  inch inside diameter, joined these tubes with the two others forming the manometer, was carried above water. The scale of the manometer was divided to millimeters.

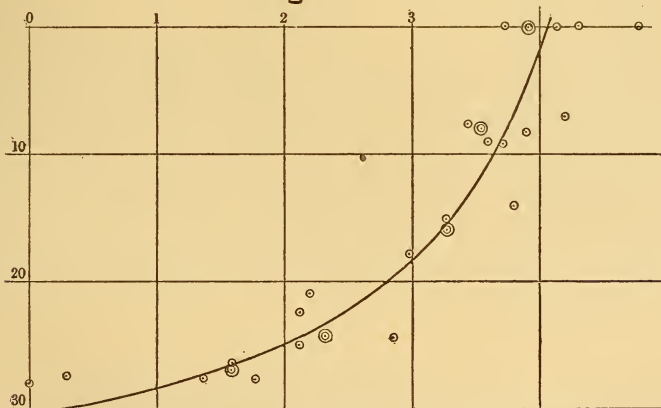
On starting out with the instrument, the tubes were all filled to a height convenient for reading, air filling the space above the water in the manometer tubes. By this instrument velocities as small as four inches per section were measured.

A few extracts are given from Mr. Buckingham's thesis for the purpose of exemplifying the use of the instrument. The river was eighty-five feet wide, and about two feet deep at the point where the gauging was made, a depth in which the meter would be almost useless.

The readings of the instrument at a point thirty feet from shore were at the depth—

	0	6	12	18	20 Ins.
	<i>mm.</i>	<i>mm.</i>	<i>mm.</i>	<i>mm.</i>	<i>mm.</i>
	6.	5.	4.5	2.5	1.
	6.	5.	4.5	2.	1.
	6.	5.	4.5	2.	
	6.	5.	4.5	2.	
Means...	6.	5.	4.5	2.125	1.
Velocity..	.342	.312	.284	.204	.139 met

Fig. 1.



These are laid off on the diagram, Fig. 1, in the double circles. The diagram contains all the velocity measurements taken for the gauging. The curve shown was struck in by eye, and is approximately the mean vertical curve of velocities for the river at the point gauged. The velocities at the different verticals, in order to combine in one diagram, were reduced to a depth of thirty inches, and a mean velocity of about 0.3 meters.

The discrepancies shown are owing

mostly to the relative velocities at different depths being dissimilar. For instance, the points inclosed in the double circles were taken at one vertical, thirty feet from shore. The best curve for these, taken separately, would be less inclined, or sloping. Again, another vertical gave the three velocities most in excess above the mid-depth, and the two most in deficiency below, the best curve for which, taken separately, would be more sloping than the one on the diagram. Owing to this disparity in the

law of variation of velocity with depth, the curves for the individual verticals show to better advantage than the mean one. A curve imagined to be drawn through the double circle dots will give a good idea of the agreement of velocities with curve at the individual verticals, and also of how the instrument, rude as it was, did its work. Considering this, together with the shallowness of stream, and its low velocity the re-

sults will probably compare favorably with any made by other means.

#### FINAL DETAILS OF THE NEW FORM.

A much better form of the instrument for use in gauging rivers of considerable depth is presented in the following figures: Fig. 2, is a representation of the sub-surface portion; Fig. 3, of the tip of the tubes; Fig. 4, the manometer; and Fig. 5 the mode of using the instrument in practice.

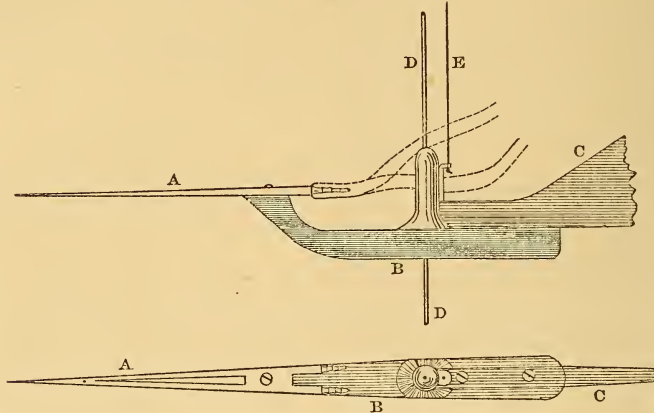


Fig. 2.

In Fig. 2, A is the tip or mouthpiece to the tubes. This tip is formed of two tubes united in front and forked toward the rear, with the two branches terminated in a shape suitable for conveniently receiving the minute rubber hose which communicate with the surface. This is mounted upon a piece B, iron or other heavy material, which serves as a sinker, and also as a holder for the vane

C for heading the instrument up-stream. B is suspended by means of a cord or wire, E extending from the surface. A hole through B receives the cord or wire D, which latter holds the instrument against the current. A should be detachable from B for two reasons: first, because the delicacy of the point requires it to be especially cared for; and second, for convenience of manipulation.

Fig. 3.



The tip, Fig. 3, is made in the same manner as in the Darcy instrument. One tube, A, is terminated by a small beak, B, headed directly up-stream in use. This should be cylindrical for such a distance from L that the increase of thickness will be beyond influencing the current to such an extent as to have any effect at L. The end at L should be reamed out to a somewhat slender cone, till it meets the exterior cylindrical sur-

face in a sharp edge. The vertex of the cone may be extended to the tube A, by a passage quite small. The effect of a very small passage is to reduce the oscillations of the columns of water above, when read. The diameter of it need not be over one or two hundredths of an inch. The diameter of the outside of L may be from  $\frac{1}{16}$  to  $\frac{1}{8}$  of an inch; though there may be no serious objection to a larger size. It appears from the descrip-

tion to have been somewhat less than  $\frac{1}{16}$  in the Darcy instrument. The height of the column being dependent alone upon the *intensity* of the pressure of current, it will be the same whatever the diameter of L. The delicacy of the sharp edge at the extreme end L makes it advisable to form it of tempered steel.

The second tube D joins the first at C, and is to be brazed or soldered, and finished smooth to prevent obstructing the current. A should be previously compressed, or filed off at the junction, so as to make room for two lateral holes at C, diametrically opposite, one above and one below, and communicating only with the interior of D. These holes should be minute, and the opposite sides parallel where pierced. This arrangement eliminates, in the best manner, any action of the current at C to modify the height of the column, even should the current have considerable obliquity.

The smallness of the openings at B and C may at first be objected to on the ground of a supposed liability to become clogged in use. The Darcy tube appears to have been a very successful instrument: and in the gauging of the Sangamon, above noticed, the glass outlets of about  $\frac{3}{8}$  of an inch diameter did not experience the slightest obstruction. This appears reasonable when we consider that there is no general rush through these openings, and that the slight currents which do take place are in opposite directions as the columns oscillate, so that any particle which may be retained at one moment will be rejected at the next.

The manometer or part of instrument by which the pressures of current are measured is very simple. A good form of it is shown in Fig. 4. Assuming the highest velocity ever encountered at 10 lbs. per sec.; 20 inches would be a sufficient length for the two glass tubes. The lower ends of these tubes should be set in sockets with proper nipples for connection, individually, with the rubber hose from below. For convenience in reading off the difference of level of the two columns in practice, it may be advisable to introduce a valve or cock at the lower end of the manometer as shown, by which the two columns may simultaneously be cut and fixed. This is all

the more necessary from the fact that the difference of column heights requires two readings, one for each tube. This arrangement is the same as that in the Darcy instrument for fixing the columns; necessary in that; provisional in this.

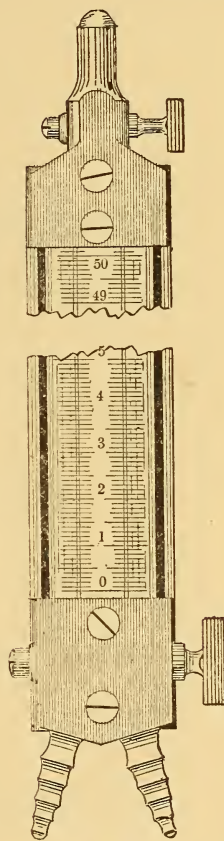


Fig. 4.

When used in this, the column heights may be averaged by sight, thus securing the advantage of accessibility of manometer pointed out above. The upper ends of the glass tubes should be secured in sockets having a common outlet, provided with a stop cock as shown. The latter enables the air to be exhausted by the mouth, and the columns brought to the desired positions on the scale; a little air being left in the top of the tubes and secured by the cock. Some clamp or other device should be provided for securing the manometer in a convenient vertical position on a standard in the boat.

## PRACTICE WITH THE INSTRUMENT.

In Fig. 5 the instrument is represented in use. The boat is anchored by two lines I and K, so as to hold it in a definite place. A cord, wire rope, or wire, D, is held tense by a sinker s. By aid of a second wire, E, the instrument is slid to any desired depth. This wire

could be coiled on a drum, the revolutions of which measure the depth to A. The rubber hose H, a quarter of an inch or less in external diameter, plays in the current like two strings. A single line of double hose would be preferable. An observer may read T as often as desired.

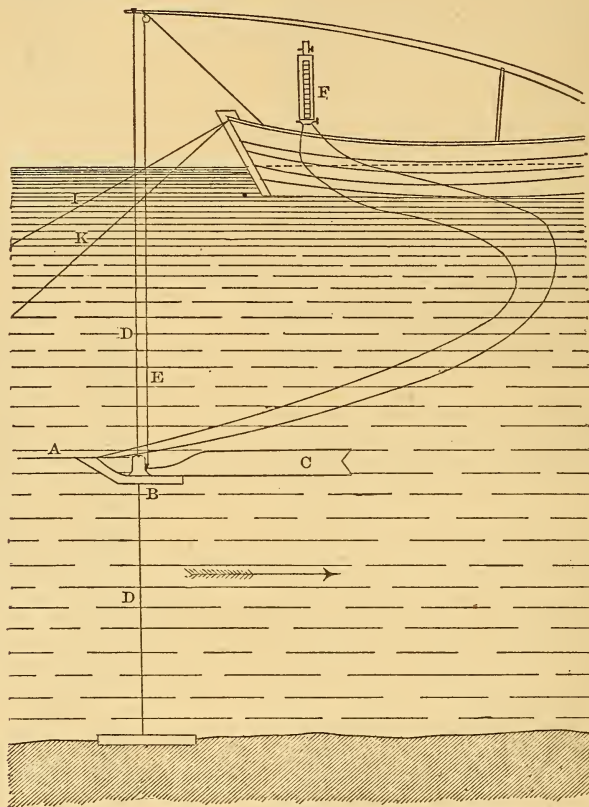


Fig. 5.

The vane C gives the instrument the direction of the current. A little consideration, however, shows that the instrument should remain fixed in the direction of the axis of the stream, and not allowed to turn about to accommodate every whirl of the current. This is true from the fact that it is the down stream component only of the velocity which is to be measured, as that to which the discharge of the stream is due. But to adopt the convenience of a wire D the turning cannot be prevented by it. It would therefore be advisable to make the vane quite long, so that it may find an average direction of current. A square pole in place of D would better

control the direction of A, but this would only be applicable in streams of say twenty feet depth or less. Nevertheless a vane is as admissible for this instrument as for any other; such, for instance, as the Woltmann's Mill, to some forms of which we have high authority for the application of the same.

When a guide line D is employed it may be advisable to stretch it, by means of a spring pole secured at the rear of the boat, and reaching forward to the desired point of location of D. This has been done in the use of a line D for carrying a mill. Such an arrangement would be almost indispensable in a stream of variable depth.

In using this instrument, it may be put in running order by attaching the hose to the manometer, and the forked tube combination A; great care being taken to make perfectly tight connections. The hose should be long enough for the deepest point in the river cross section considered. But for less depth, shorter hose might of course be used, but there can be little if any objection to either allowing the slack hose to fall back in a loop in the stream, or to be taken up and placed in the boat. Great hose length will serve the purpose of steadying the column of water in the manometer. The instrument should then be filled with water by submerging A, and withdrawing the air by applying the mouth of the tube surmounting the manometer, Fig. 4. The stop-cock retains the columns at the desired heights. The instrument may at first be filled, and a quantity of water drawn from the nipple, if there be suspicion of the presence of air bubbles in either hose or connection. A momentary opening of the cock returns the columns to the proper level. When all is correct the water should stand at precisely the same height in the two manometric tubes for still water. To insure still water a bucket may be placed in the stream, filled, and its brim brought slightly above the surface while A is within it. Submergence of the bucket will replace A without danger of its taking air, without raising above water, it may then be mounted upon B, the latter being already in position upon D.

If the convenience of a colored fluid in the tubes of the manometer be desired, let A be submerged in fluid of the desired color, as the instrument is filled. As there is no progressive current through the tubes, the colored fluid can only disappear by diffusion through it, which would require days. As the diffusion may possibly be unequal in the two branches, the precaution should be taken to employ a colored fluid of the same density as the river water.

#### THEORY OF THE INSTRUMENT.

The theory of this instrument is the same as given by Pitot to the French Academy of Sciences in 1732. It is simply this, viz.: that the difference of level of the two columns is the height

due to the velocity of the current driving against the direct opening of the tube. Hence

$$v = \sqrt{2gh}$$

where  $v$  is the velocity sought,  $g$  the acceleration of gravity, and  $h$  the difference of level of the two columns.

#### "TARE" OF THE INSTRUMENT.

Darcy, in applying his form of the tube, proceeded as though the instrument required a coefficient to change these theoretical to the actual velocities. After making a great number of observations under varying condition, such as placing the instrument in running water, then towing it in still water, with different velocities for each, he found that the mean of all the values, which agreed admirably, gave the coefficient 1.0. This, on the supposition that Fig. 3 requires the same value as Darcy's, makes the above theoretical formula of Pitot the proper one for computing the actual velocities for the new instrument. This, however, should be tested for each tip, Fig. 3.

#### MERITS AND DEMERITS COMPARED WITH OTHER INSTRUMENTS.

In comparing the instrument which forms the subject of this article, with others which have been applied to a similar purpose, we may draw the following points of comparison. Reasons were given at some length in a previous article in this *Magazine*\* why the *Moulinet*, or *Mill*, or *Current Meter* form of instrument was given preference by leading authorities for measuring the velocity of running water. It will therefore be only necessary to consider this in the comparison. Of these, we will only compare with that one which is acknowledged on good authority to be superior to all the rest as regards the arrangement of the mill and its register. This arrangement places the latter in a boat, or on shore, in telegraphic communication with the mill, while that is placed and run at the different points of depth sought, as in the Henry current meter, or Moulinet. For an elaborate illustration and description of this, see the Journal of the Franklin Institute for May 1869, p. 308.

Both the present form of Pitot's tube

\* See Vol. XIII, p. 99.

and the current meter require nearly the same accessories, such as boat, anchors, sinker, guide line, sinking line, spring pole, etc. As regards the possible frequency of reliable single readings there is probably but little difference. But when we reflect that with the new instrument single readings, no matter how oft repeated, will each give a good result, while the meter requires not only two readings for a result, but a considerable intervening time, it is plain that the tube will multiply results of velocity much the fastest. But this apparent advantage is offset, in a measure, by the fact that the result by meter will be a mean for the time, while several results by tube will be required for a good mean, which eliminates the fluctuations of current.

Perhaps the most important advantage in the tube consists in the reliable nature of the constant or multiplier for the instrument, or *tare* as it is called by Gen. Morin; the factor by which the readings are reduced to the velocity. This is found to be simply unity, as above explained, for the tube, with perfect immunity from change so long as the tips of the tubes are kept in good condition; which is easily done because the detachable part A, Fig. 3, is so compact. But in the meter, the wheel is more liable to derangement by being bent, or grit may effect its freedom of rotation slightly, so that elaborate experiments are necessary to determine the tare; equally elaborate ones being necessary every time there is suspicion of the slightest change in the value of the tare from wear or other damage to the parts. Indeed this continual embarrassment with the tare of meters is by many esteemed a very serious if not fatal drawback with it. Again, every new meter, because perfect duplication is impossible, must have its tare found with equal care with any other; while any tube, new or old, made as above directed, will probably be found to always have precisely the same tare, rendering repeated elaborate observations for it unnecessary. Furthermore, the tare, or multiplier for the meter, is not a constant, so that a table of multipliers is required, sufficiently comprehensive to extend to every velocity met with in practice. This supernumerary nature of the multiplier necessitates observations

for determining, as it were, a great number of values of the tare. For instance in one telegraphic current meter it ranged from about 12.5, for a velocity of .5 feet per sec., to about 8.5 for a velocity of 4.5 feet per sec., all values lying in a curve almost elliptical. But in the Darcy form of Pitot's tube, the tip of which is very nearly as in Fig. 3 above, and upon which only the tare depends, the tare is found to differ inappreciably for velocities ranging from 2 to 6.5 feet per sec.\* Hence, considering that the tare is not only constant, but unity in the best forms of Pitot's tube, while in other instruments it is neither constant nor unity; the advantage of the former over the latter in this respect is not only decided but important.

In regard to compactness and simplicity, we observe that all the parts of the present form of Pitot's tube requiring delicate manipulation, are represented in Figs. 3 and 4, which would require a special packing box for rapidity in transportation. The parts, however, are wholly devoid of machinery and wheel-work, and hence more simple than current meters, all of which require clock-work registers. The telegraphic meter requires also a battery and all its indispensable accompaniment and care, the meter and clock-work being, in this case, detached parts and each very delicate pieces of mechanism.

The office work will differ but little in the two instruments, the meter observations requiring the number of revolutions to be divided by the time, which number per unit of time will give the velocity by aid of a table. The tube requires the velocity for each height—read off, which is readily looked out from any ordinary table of velocities due to heights. Any difference of labor there may be in these two processes is evidently in favor of the latter.

One point of superiority of the tube over the meter, especially in shallow streams and channels, otherwise narrow, such as *conduite* tunnels, pipes or sections of orifices, &c., consists of the minuteness of the locality in the current at which the observation can be confined with the tube, whereas the meter requires room for the movement of the

\* See Morin's *Hydraulique*, p. 140.

wheel. In such cases, indeed, the velocity may be appreciably different within the space occupied by the wheel.

Finally, in the matter of first cost, the tube instrument has much the advantage. This is evident from the fact that the number of parts is much less, and the form of parts more simple. The parts of mechanism are not only more complex than devices consisting of fixed parts, but require, in addition, very careful

adjustment in order to secure the necessary freedom of motion. Again, nicety of construction in current meters, is an indispensable pre-requisite for precision of results, as well as for convenience in use, while in the tube instrument the rudest arrangement will serve a very good purpose, as evinced by the example cited above, nice construction having for its chief object only the secondary consideration of convenience in use.

## THE NEW MEASUREMENT OF THE SUN'S DISTANCE.

By RICHARD A. PROCTOR.

From "English Mechanic."

Two measurements of the sun's distance have recently been announced, as the result of observations made during the transit of Venus in December, 1874, by the British observing parties. One has been deduced from the telescopic observations, the other from the photographic records. I propose briefly to consider the significance and value of the new results, or rather of the former result, for the result of the photographic operations may be summed up in a single word—"failure." Every one knows that the estimate of the sun's distance which was in vogue a quarter of a century ago (95,365,000 miles) was reduced by four million miles in 1854. The older estimate had been obtained from observations of the transit of Venus in 1761 and 1769; the new estimate from other methods which need not here be described. It was supposed, however, that transit observations were likely to reassert their value in 1874, and again in 1882, when they were to be applied with modern refinements. In the meantime, fresh measures were made by the other methods, and the observations of 1761 and 1769 were re-examined. Mr. Stone, of Greenwich, made them agree in a very satisfactory manner (or rather to a very satisfactory degree) with the new estimate. But Continental and American astronomers objected to his way of dealing with the old observations. The new measures also contradicted Stone's results. Newcomb, of Washington, who has more thoroughly mastered the gen-

eral subject than any living astronomer, deduced from six sets of observations by the best available methods, the distance 92,390,000 miles—round which all the best results by these methods clustered very closely. This was nearly a million miles greater than the reduced estimate adopted in 1854; but still fell nearly three million miles short of the distance taught in all the text books of astronomy between the years 1810 and 1850. Leverrier, adopting a method of his own—a method, indeed, which none but he could have applied with any effect, seeing that none but he possessed at once the requisite mathematical power and the requisite gathered knowledge—arrived at almost exactly the same result.

Astronomers accepted 92,400,000 miles, therefore, or some value between 92,300,000 and 92,500,000 miles, with considerable confidence.

The result of the British operations, however, is a distance of 93,375,000 miles—two million miles less than the old estimate, two million miles greater than the estimate of 1854 and Stone's much-lauded deduction from last century's transit, and about one million miles greater than the values obtained by Newcomb and Leverrier.

The result would be inadmissible if all the details agreed closely among themselves. But fortunately or unfortunately (fortunately for science certainly) the details do not agree among themselves. The sun's distance can be inferred from

the observations of the beginning of transit, and also independently from the observations of the end of transit. As determined from the beginning it comes out a million miles greater than as determined from the end of transit. Observations so widely discordant cannot, of course, establish a result (their mean) which is itself widely discordant from the mean of many closely accordant sets of observations.

The new determination, therefore, possesses very little weight; yet we must not fall into the error of supposing that those who have been engaged in obtaining it have failed to exercise proper care or to display proper energy. I believe that, on the contrary, they deserve all praise for care and caution on the one hand, and on the other for zeal and energy. This opinion is not based merely on the statement of their official superior, who, being responsible for their selection, might be prejudiced in their favor, but on independent considerations. Nor must the failure be attributed altogether to the selection of an unsatisfactory method of observing the transit. I was myself very little disposed to view with favor the exclusive reliance placed by our chief official astronomer on that method, commonly called Delisle's, and *more meo* I expressed my views on the point with some distinctness, and emphasized them with some effect, at the proper time. But, apart from the fact that it would now be of very little use to indicate objections, even at that time, I should have been very sorry to see the method in question neglected; and the final arrangements did little more than assign to it a just amount of attention (albeit it was a little unfortunate that nearly the whole use made of it was by our British expedition). Undoubtedly the method has now been proved to be practically valueless. Nothing done by it can ever be of use as a correction on the results obtained by superior methods. Applied in 1874, it gives better results than better methods applied with defective appliances in 1769, and applied in 2004 and 2012 it would possibly serve to correct the best measures we have now. But it will always be inferior to other methods applied with equal instrumental means and equal observational experience.

This result, though obtained at rather a heavy cost, may be regarded as a valuable first fruit of the transit observations in 1874. In the meantime, many of the British observations made at southern observing stations will be combined effectively with observations made by Russian, American, and German astronomers in the Northern hemisphere, and we may still find the British work effective in the deduction of positive results, apart from the important negative results I have already indicated.

The British photographic operations have ended, as already mentioned, in failure. The resulting estimate of the sun's distance ranges from 100,000,000 miles to and beyond infinity! Beyond infinity must be understood to mean that, according to certain photographs, interpreted mathematically, the sun was not at such-and such a distance on the side towards which he was seen, but was on the other side altogether—one of those utterly unimaginable results in which mathematical calculations occasionally issue. Of course the real meaning is that the photographs are altogether valueless.

This is a disappointment, as much was expected from this method. I remember well the exemplary gravity with which, at a meeting of the Astronomical Society, our chief Government astronomer (for convenience of reference called Astronomer Royal for England) described the plan for taking several photographs in rapid succession. The plan was based, he told us, on the principle of the hurdy-gurdy. He illustrated this in action with considerable success, the general effect being strengthened by the circumstance that only a few minutes before the performer had read one of the fellows (myself, if I remember rightly) a lesson on the impropriety of smiling at aught that may be done by official astronomers. But the photographic hurdy-gurdy has not proved a success.

For the present we must remain content with Newcomb's value as probably the nearest approach yet made to the true distance of our sun. But, for my own part, I expect excellent results from the expedition by Mr. David Gill to Ascension Island last autumn, to observe Mars and two of the minor planets, for the purpose of obtaining materials

whence the sun's distance may be deduced. He has obtained the materials, and before long we may expect to learn his estimate of the sun's distance.

One remark in conclusion, as to the work of official astronomy in these matters. It seems to be supposed by some that the chief Government astronomer is set over other astronomers; and that it is a point of discipline to approve of all he does. Of course, this is altogether a mistake. So far is it from being true that the precise reverse is nearer the truth. All Government astronomers are under authority, so that an astronomer who is not under authority is in that respect above them. But without insisting on this obvious point, it must be noted that our Government astronomers (whose special rule, by the way, bears about the same relation to real astronomy that land surveying bears to geology) are the paid servants of the nation; and the results of paid service may rightfully be examined by those who pay for it. Now, in the present case, if the labors and plans of Government astronomers are not criticised by independent astronomers, by whom can they be? The official chiefs of the admiralty are not expected to know anything of astronomy,

and they do not disappoint expectation in this respect. Official astronomers in different departments are apt to pat each other on the back. Subordinates know their duty (I will not say their interests) better than to note any defects in the plans of their superiors. Unless, then, there is criticism by independent astronomers, there will be none at all. (Too often there has been none where criticism was very much needed). But service, the fruits of which are only to be appraised by those who are paid for doing it, is an anomaly and an absurdity.

Our salaried astronomers may be assured, also, that in public estimation the approval (even the moderate approval) of the independent astronomer weighs more than any number of laudatory comments by themselves (or their subordinates) on their own work. When, for instance, I say, as I can truly say, that in my belief Sir G. Airy's official work will not suffer by comparison with that of the most eminent of his predecessors in office, every one knows that my opinion is unbiassed; but when he himself assures us that "nothing can compete with" the transit observations for which he is responsible, people scarcely know what to think.

## COMBUSTION OF FUEL IN BOILERS.

By CAPT. HAMILTON GEARY, R.A.

"Journal of the Royal United Service Institution."

It is not my intention to enter into a discussion on the general question of the combustion of fuel for steam purposes—a question I am sure which needs no explanation on my part—but, I hope to bring before you a *particular* method of treatment which I have found experimentally successful, and which I have endeavored to protect by a patent.

The subject naturally divides itself into two parts, first, the *fuel*, secondly, the *boiler*; each of them, I take it, of equal importance.

1. *The Fuel*.—I think it may be laid down as an axiom that *theoretically* the most advantageous fuel is that containing the largest percentage of carbon. But such is our want of ability or prac-

tical knowledge, that the richest fuel this country produces, rarely, if ever, finds its way into our coal-bunkers. I allude to the anthracite coal of South Wales.

A glance at the table will substantiate my statement—

(See Table on following page.)

The table represents the average composition taken of twenty specimens of British coals. Under A we have the average of five specimens of caking coals; under B of five of non-caking coals; under C of five of cannel coals; and under D of five of anthracite coals.

Perhaps some present may take exception to the deduction I make from a consideration of this table, that the coal

## ABSTRACT OF AVERAGE COMPOSITION OF BRITISH COALS.

Composition, per cent., exclusive of water.

Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.
A. 79.71	5.25	1.85	0.71	9.30	2.12
B. 76.04	4.75	1.80	0.64	9.75	2.58
C. 77.71	6.34	1.06	1.02	7.00	6.24
D. 90.60	2.96	0.77	0.32	1.92	3.44

under D has a far higher calorific power than the others by pointing to the much greater proportion of hydrogen contained under C, for example, and reminding me that the calorific power of hydrogen varies between 34 and 35 thousand. I think a little consideration will remove this, at first sight, natural objection.

In all fuel containing carbon, hydrogen, and oxygen, there is *invariably* sufficient hydrogen present to form water with the oxygen; in fact, it is *only* the hydrogen in *excess* which is available for heat-giving purposes.

Indeed, so eminent an authority as Dr. Percy considers that the hydrogen and oxygen contained in a fuel may be taken as water already, so that the carbon *alone* is the source of heat, and the carbon cannot be burned without the evaporation of this water, at the expense of the heat developed by its own combustion.

The hydrogen may and does undoubtedly assist materially in the generation of *flame*, but it is equally true that that portion which exists with the oxygen in the state of water, not only *does not* contribute to the *actual* amount of heat produced, but consumes no inconsiderable portion of it.

It is, therefore, evident that, could we so contrive boilers, or what is better still, adapt our existing boilers to burn this particular fuel with advantage, we should have made a great stride towards both efficiency and economy.

Anthracite, however, is subject to certain disadvantages when applied for steam-boiler purposes. In the first place, it is divided into two great classes, one of which "clinkers," and so requires a special arrangement of fire-bars. Again, the heat is intensely local, and with ordinary boilers does not flame. This is a manifest disadvantage with tubular boilers. The decrepitating variety of anthracite is the one most prevalent in

the coal derived from the Welsh coal measures.

The practical disadvantages to the employment of anthracite, are the difficulty of utilizing the slack, of which a large percentage is formed in the manipulation of the coal, and its tendency to split up into small fragments when suddenly heated. The resulting dust forms, with the cinder, pasty masses, which cannot be burned away, and either choke the furnace or otherwise seriously upset its working.

These difficulties in the way of employing anthracite, have led from time to time to various attempts being made to derive from it a serviceable coke.

None of these have, as far as I am aware, been commercially successful, for although coke was certainly produced, it was friable, and generally of inferior quality.

Messrs. Penrose and Richards, of Swansea, in 1874, appear to have successfully solved this problem. It is not the time this evening to enter into any detail of the process of manufacture adopted by them; it will suffice to point out that experience has fully justified the estimate I have ventured to make with regard to their coke; indeed, the comparative trials made at the Landore Works, some of which I have had the privilege of witnessing, and the manifest superiority of the anthracite coke to *all* others employed in the blast furnace, have led me to the consideration of the practicability of employing the same for steam-boiler purposes.

TABLE SHOWING PERCENTAGE COMPOSITION OF DRY COKE.

A.	
Carbon.....	89.58
Hydrogen.....	0.44
Oxygen and Nitrogen....	1.92
Sulphur.....	0.38
Ash.....	7.68
	100.00

B.	
Carbon.....	94.63
Hydrogen.....	0.30
Oxygen and Nitrogen....	1.48
Sulphur.....	0.23
Ash.....	3.36
	<hr/> 100.00

the anthracite coke under B has a higher calorific value than the coke under A, which represents the average composition of three different specimens of British coke. Again, the resulting ash is *one-half* in the case of the anthracite coke to that from other coke.

A glance at the table will show that The specimens of this coke on the

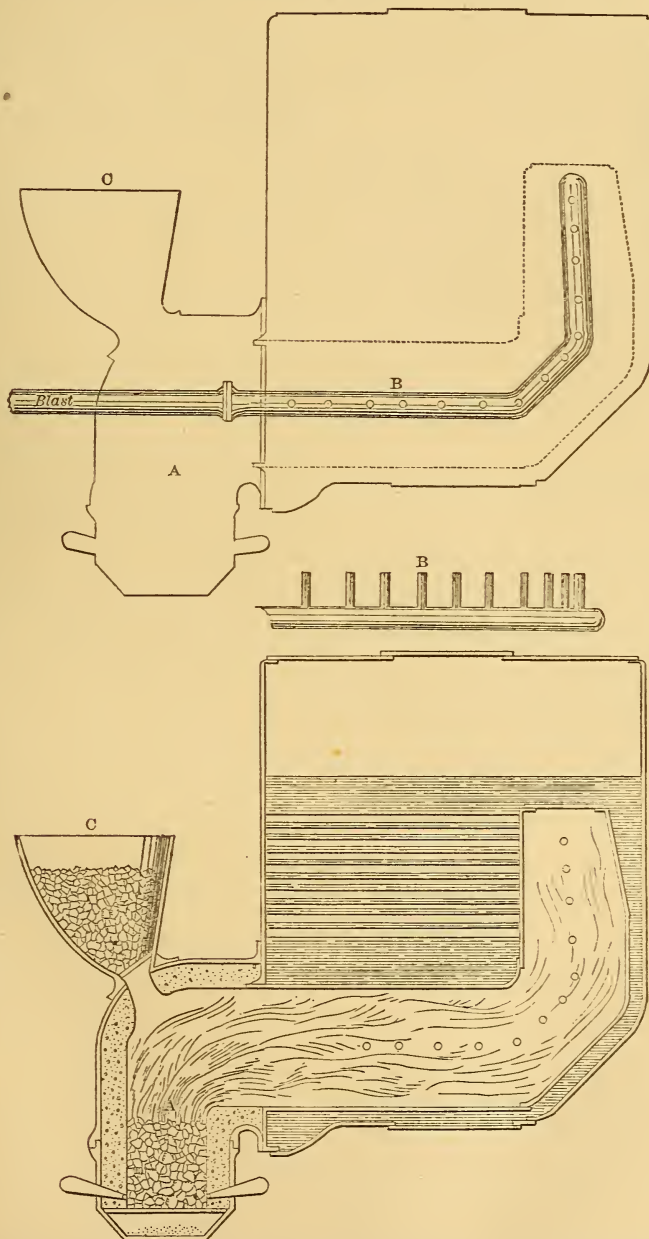


table have been taken from a heap exposed freely for the last eighteen months to the action of the atmosphere. It has suffered in no particular.

It still presents its characteristic steel-gray metallic appearance, nor did the pile from which it was taken show any sign of crumbling.

It may be as well to enumerate the advantages claimed for this fuel over other coke.

1. Higher calorific power.
2. Much greater hardness, indeed much harder than the anthracite itself.
3. In burning under blast or otherwise, with or without burden, it neither crumbles nor decrepitates.
4. It is about 23 per cent. heavier than the north country coke. Indeed, a vessel recently laden with 240 tons of the latter was able to take in 310 tons of anthracite coke.
5. Ordinary coke absorbs, when soaked, 10 per cent. and even more of water; anthracite coke between 1.5 and 2 per cent.
6. The low percentage of ash reduces the dust to a minimum, and the combustion of the fuel is unattended by any smoke.
7. The loss by crumbling is inappreciable.

These admirable qualities, as I have before stated, led me to consider the very great advantages which would accrue should it be possible to burn the anthracite coke in connection with steam boilers.

The problem to be solved consisted, 1st, in producing sufficient flame; 2d, in burning the fuel with economy. The hardness and density of the fuel necessitates a high temperature to ignite it, and for this purpose a blast of air or steam must be employed.

By bringing the zone of combustion closer to the tuyères, there arises a diminution of the waste of fuel in the upper part of the furnace. But it would be as well to proceed to the consideration of the boiler and furnace itself.

As shown in the diagram, I separate the furnace from the boiler proper, in fact the furnace becomes a gas generator, A. This generator is constructed much as an ordinary cupola furnace, closed at the interior part. The exterior is composed of iron rings or cylinders keyed together, and the joints stopped with fire-clay. The top is of a cowl shape, and fits tightly against the boiler face. The interior is lined with fire-brick or

clay. As the anthracite coke produces but a small proportion of ash and that finely divided, it readily drops through the fire-bars into the ash-pit below. The blast keeps the fire-bars cool by striking above them. The diameter of the generator is the same, or nearly so, as that of the boiler tube, and I have found a depth of eighteen inches of fuel sufficient to produce the requisite reactions.

As is well known, the  $\text{CO}_2$  formed at the interior part of the furnace in passing through the incandescent carbon is reduced to  $\text{CO}$ , and in that condition escapes from the surface of the burning mass. It now becomes a question how to supply the necessary oxygen for the combustion of this  $\text{CO}$ , and when supplied how to regulate the same, and produce a large heating surface for the boiler.

This is managed by means of the tube (B) passing outside the boiler, perforated with holes at stated intervals and of known diameter, into which hollow tubes are fixed, which, passing through the water, act as stays to the boiler itself, and open out into the main tube or flue of the same. Through this pipe air is driven.

It will be seen that the  $\text{CO}$  formed at the surface of the fire will have to seek for the necessary oxygen from the various orifices in the tube, in order to burn and be converted into  $\text{CO}_2$ ; but as the supply of air is limited from each orifice, the unburnt  $\text{CO}$  will be induced to move forward to the next and so on, so that we can draw the hot flame of burning  $\text{CO}$  to any practicable distance.

I have found that the heat in the boiler is sufficiently high at the remote end to enable this to take place; and, moreover, this is assisted by the fact that the air which finds its way into the boiler tubes, is heated by having passed in close contact with the boiler, and the boiling water itself. This, of course, reduces the quality of heat consumed in raising the air injected.

Steam decomposed by heated carbon instead of air, would theoretically be preferable, as we should not have to waste so much heat in raising the temperature of the useless nitrogen, and we should have available the hydrogen, and there is nothing in the nature of the boiler and gas-producer I have described

to prevent its employment; but hitherto I have been content with air, which has answered very well, and is more easily and readily available.

The tube arrangement for injecting air or steam into the flue of the boiler admits of regulation in case of necessity, either by reducing the blast, or by closing one or other of the orifices.

As regards feeding the furnace: A hopper arrangement (C) with sliding plates covering the entrance to the gas-producer, will enable one to charge the furnace mechanically, and entirely obviate the necessity of stokers.

The coke naturally splits up into long fingers presenting the appearance of the samples on the table, so that no labor need be expended in reducing the bulk of the pieces.

The chucks will fall vertically into the furnace, and a small peep-hole enables the fireman to regulate the depth of his fire. The smallness of the pieces of coke, allows a corresponding diminutive opening between the hopper and the furnace, and so diminishes the escape of the heat.

I have now described generally the nature of the construction of the boiler apparatus, I prefer; a careful regulation of the blast will enable us to burn the fuel to a nicety as regards economy, the closing of the furnace economises heat, and keeps the stoke-hole cool, whilst the vertical method of charging obviates the expensive and distressing operation of stoking.

It will be necessary now for me to bring to your notice the results of the experiments I have been able to make.

Last year, having been satisfied as to the practicability of producing a large body of flame from the anthracite coke, sufficient in itself to produce a working head of steam in an ordinary locomotive boiler, this year at Neath, on 31st May, and 1st and 2d June, the following more exhaustive experiments were carried out, and with these results:

#### TRIALS OF COALS AND PATENT ANTHRACITE COKE.

May 31st, June 1st and 2nd, 1877.

##### *Trial No. 1.—Steam Coal.*

Fired under boiler at..... 11.0 a.m.  
Steam gauge started from zero at.. 11.17 a.m.  
Steam blowing off through safety-valve and steam gauge showing pressure of 32 lbs., at..... 12.15 p.m.

Time taken to raise steam to 32 lbs. = 58 mins.  
Weight of coal used, 2 cwt. 2 qrs. 25 lbs.  
Specific gravity of coal, 1.320.

##### *Trial No. 2.—Anthracite Coal.*

Fired under boiler at..... 2.15 p.m.  
Steam gauge started from zero at.. 2.26 p.m.  
Steam blowing off and steam gauge showing pressure of 32 lbs. at... 3.18 p.m.  
Time taken to raise steam to 32 lbs. = 52 mins.  
Weight of coal used, 2 cwt., 2 qrs., 12 lbs.  
Specific gravity of coal, 1.370.

In both the above cases the quantity of cinder withdrawn was inappreciable.

##### *Trial No. 3.—Patent Anthracite Coke.*

Fired under boiler and blast turned on at..... 4.4 p.m.  
Steam gauge started from zero at.. 4.13 p.m.  
Steam blowing off and steam gauge showing pressure of 32 lbs. at... 4.45 p.m.  
Time taken to raise steam to 32 lbs. = 32 mins.  
Weight of coke used,..... }  
Weight taken out after trial, }  
    { 2 cwt. 1 qr. 4 lbs. }  
    { 1 cwt. 2 qrs. 7 lbs. } = 2 qrs. 25 lbs.  
Specific gravity of coke, 1.200.  
Quantity of blast used = 953 c. ft. per minute.

Description of boiler in which trials were made:

Shell, 20 ft. × 3 ft. diameter, with  
2 tubes, 20 ft. × 12 inches diameter.  
Fire place 3' 3" long × 2' 8" wide.

From this experiment it follows that a boiler employed as I propose is superior, as regards fuel consumed and the speed of producing a certain result, to a similar boiler fired under ordinary considerations in the proportions of 6.8 to 1.

For if A does in thirty-two minutes a work at an expenditure of 81 pounds of fuel, and B to do the same work takes fifty-eight minutes with an expenditure of 305 pounds of fuel, we have the proportions—

$$A : B :: \frac{1}{32} : \frac{1}{58}$$

$$A : B :: \frac{1}{81} : \frac{1}{305}$$

$$\therefore A : B :: (58 \times 305) : (32 \times 81)$$

$$\therefore \frac{A}{B} = \frac{6.8}{1}$$

These, I submit, are very important results. It is readily conceded that had a blast and gas generator been applied to the trial with steam coal the results would have been modified; but one of the chief objects of the experiment has been to show as much the superiority of

the method of burning a fuel over that in common use, as the superiority of the fuel itself.

We must now consider, before being able to arrive at a definite conclusion as to the relative merits of this or that system, what is the *cost*.

The cost of anthracite coke at the ovens is about 15s. 6d. per ton.

Taking the average price of steam coal at the pit's mouth to be 10s., there is a balance in favor of the steam coal of 5s. 6d. per ton.

Taking weight for weight, as shown by the experiment quoted, *to do the same work, neglecting the time*, one ton of anthracite coke is equivalent to 3.768 tons of steam coal, and hence we have the relative cost as 1 to 2.34 for any specific work required.

So that, in point of fact, although anthracite coke is much more expensive than steam coal, in its employment it is less than half the price.

There is the important question of relative bulk to be considered. A given weight of anthracite coke occupies a space, as compared with the same weight of steam coal, represented by the proportion 13 : 10, from which it is evident that the bulk occupied by anthracite coke in a vessel to send it a given voyage, when compared with the bulk of steam coal is 345 : 1000—

$$\text{Because } A : B :: 305 : 81$$

$$A : B :: 10 : 13$$

$$\text{Hence } A : B = 1,000 : 345;$$

or, in other words, the anthracite coke would occupy but one-third of the space required by the steam coal, leaving the remainder for freight, or in the case of ships of war for additional fuel.

I have now considered the chief features of the fuel and the boiler. Before recapitulating, it would be advisable to endeavor to meet and explain any difficulties which, I am sure, will have suggested themselves to many of my hearers.

1st. As to the practicability of producing the requisite blast, and then the loss of power thus entailed.

Most steam-ships possess a donkey engine. Such an engine, or indeed one of far inferior power, would be amply sufficient to supply the blast required. In the case of the experiment to which I

have adverted, the pressure of the blast was 5 inches or  $\frac{1}{4}$  lb., which I think is so small as to need no particular allowance to be made for it. This blast was sufficient to supply 953 cubic feet of air per minute to the furnace.

A stronger blast would produce more speedy results. When once a head of steam had been attained, a rod from the shafting of the engine itself would be sufficient to continue the blast, and liberate the donkey engine if necessary. Indeed, on an emergency the fire could be got up by a hand-blower.

2d. Supposing the furnace to get out of order, how is it to be repaired at sea, for example? Most steamers have more than one boiler, and as there would be a furnace to each boiler, the vessel could proceed whilst the damaged furnace was being repaired.

Every vessel would carry some spare iron casings, and also fire-bricks, or such cylinders of fire-clay of the requisite size, as are made of Stourbridge clay every day to order. Should such cylinders be employed, a new furnace could be erected and in work in the space of three hours.

Moreover, there is nothing which could cause damage to the furnace, or render it unserviceable, except the burning away of the fire-clay.

The fuel *not* being in the presence of iron, as in a cupola furnace, the life of the clay is greatly prolonged. The roof of a reverberatory furnace in the Arsenal is found to last without repair for nine months, and therefore we may reasonably conclude that the furnaces of a sea-going steamship would not need repair so frequently. This operation is inexpensive, as the cost of the fire-clay cylinders for a furnace with a radius of 12", and depth of 36 inches, would be about £3.

As regards the filling of the hoppers (which would be covered to prevent the scattering of the fuel when there was a lurch), this could be arranged by a Jacob ladder from the coal bunkers direct, and so the lifting of the fuel by manual labor would be avoided. Indeed, were one to build a vessel expressly with a view to the employment of this particular boiler, the level of the coal bunkers could be so arranged as to obviate this necessity, for the top of the hopper need

not be more than four feet six inches to five feet above the level of the engine floor. Again, as regards the complication of the waste-pipe arrangement by which the flame is drawn through the boiler-tubes, though I consider it to be a decided advantage, as regards the efficient burning of this or other fuel, the boiler would work favorably if an excess of air were blown in at the tuyères, sufficient to supply the necessary oxygen for the combustion of the CO.

The short tubes or stays communicating with the boiler-tube tend to strengthen the boiler itself.

3d. As to the supply of the fuel, anthracite has been but little employed in this country as compared with other coals.

For malting, and for a little copper smelting, it has been used for some time, but it is only lately that attempts have been made on any scale to take advantage of its high calorific power, and of its comparative purity, to use it in steam boilers. Even then a considerable proportion of other coal has to be employed, which detracts greatly from the results obtained from the use of the anthracite.

We may therefore consider our vast anthracitic basin at our disposal *intact*; and its employment in the form before us will give us the maximum of its valuable properties with a minimum of waste, for the slack of anthracite is *admirably* adapted for the manufacture of anthracite coke.

It only remains for me briefly to recapitulate the advantages claimed by the use of a particular and readily procurable fuel, and then when burnt in a particular way, as compared with the method of fuel in common use.

I. To do a given work there is a saving of between three and four times the fuel by weight.

II. There is a saving of two-thirds the bulk and consequent gain of freight.

III. The cost of the fuel alone is less than one-half.

IV. There is no appreciable loss by weathering, or by disintegration.

V. Stoking, as at present carried on, is obviated.

VI. The fuel is more completely consumed.

VII. The fuel is not liable to spontaneous combustion.

VIII. It absorbs one-fifth the amount of moisture.

XI. On account of its purity the boiler is not burned.

X. There is an absence of dust and smoke.

XI. The engine room is both cool and clean.

The advantages which would be derived by a fleet from a successful application of some such method can hardly be exaggerated. Its strength would be more than doubled. Apart from the question of cost, a war vessel would be able to treble its voyage without calling at a coaling station; the number of coaling stations could be reduced, and a large store of fuel could be kept in any climate without fear of deterioration. The flame and smoke from the funnel, which render a war steamer a target by night, and the discoverer of its own track by day, would be no longer found.

In conclusion, I beg leave most earnestly and emphatically to disclaim any idea of having made any startling discovery; my sole object in coming here this evening is to lay before you the results of experiments and experiences which have occupied my attention to a great extent for the last few years, in the hope that I may have assisted, in however humble a degree, in helping forward one of the great questions of the day, and one which so urgently calls for a satisfactory and speedy solution.

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A DESCRIPTION of a simple contrivance for the rapid cooling of liquids, invented by M. Toselli, is described in *Les Mondes*. It consists of a cylindrical cup, for holding any liquid, into which may be plunged an inner goblet, shaped like an inverted truncated cone, and having a lid which rests on the outer cup. Putting 150 grammes of nitrate of ammonia in the inner goblet, filling it with cold water, and stirring it so as to hasten the solution, the temperature of the outer liquid is soon reduced at least 12° deg. C.—22 deg. Fah. The salt may be used for an indefinite period, by spreading it on a plate after each trial, and exposing it to the sun until it crystallizes anew. The inventor prepares a salt which will lower the temperature 28 deg. C.—50 deg. Fah.—in the warmest countries.

## THE SEWAGE OF LONDON.

From "Nature."

THE question of the effect of the main outfall sewers of the metropolis on the reaches of the Thames below London has occupied the attention of engineers not only since the completion of the works, but throughout the long series of years when those works were under consideration. Some persons, qualified to make accurate observations and draw correct deductions from them, asserted that large masses of deposit were directly due to these outfalls, and were daily increasing in magnitude, while others, demanding equal confidence in their statements, asserted that no such deposits existed—in fact, that the sewage outfalls tended to improve the bed of the river by increased scour; thus the bulk of engineers for a long time held diverse views or suspended judgment on the subject, while the general public, not knowing whom to believe, trusted it would turn out all right in the end. Inasmuch as the Metropolitan Board of Works is bound, under the Thames Navigation Act of 1870, to keep the Thames free from banks and other obstructions to the navigation due to the flow of sewage from their outfalls, and to carry on all dredging operations required for that purpose, at their own expense, the vision of the possible cost of these works to the London ratepayer is unlikely to be pleasing; still less could any interference with the highway to the most important port in the world be tolerated by the Board who were looked to for its preservation. In 1869, the metropolitan main outfalls having been opened in 1863–64, the Home Secretary appointed Mr. Rawlinson to hold an inquiry on the reported silting up of the Thames, which was then causing great alarm; such, however, was the contradictory nature of the evidence, that the result was almost nugatory, and the question still remained in abeyance. In the course of the last summer the Thames Conservators requested Cap., Calver, R. N., F.R.S., to direct his attention to the subject, and report to them thereon. Before pointing out the conclusions ar-

rived at by Capt. Calver,\* it will be as well to direct attention to the part of the river under consideration. The northern outfall is situated immediately above Barking Creek, which forms the embouchure of the river Roding, and is about two miles below Woolwich; the southern outfall is about  $2\frac{1}{2}$  miles lower, or  $4\frac{1}{2}$  miles below Woolwich.

In the face of the fact that this special inquiry was held and many competent witnesses examined with the sole object of determining whether or no the sewage outfalls have caused a silting up of the river in their neighborhood, or the formation of shoals and mudbanks, and that so many observations and statements have since been made with the same view, it seems perfectly monstrous that the question should still remain unsettled. In the report now before us we have the last contribution on the subject, or perhaps, with more fairness it might be said the last but one, as since its publication Sir Joseph Bazalgette has addressed to the daily press a letter containing a direct denial of many of the conclusions there arrived at. When professional experts differ so entirely not only in their conclusions, but also in the facts upon which these conclusions are based, we see no other course open but to appeal to the cooler and more unbiased judgments of pure science.

In comparing the analyses of Thames mud from various parts of the river, given in Capt. Calver's report, embodying a series taken in 1867, and another in 1868, by the late Dr. Letheby, with those given by Dr. W. A. Miller, and Dr. W. Odling in 1869, so close an agreement is manifest that a safe conclusion can be drawn from them. The analyses are as follows:

## AVERAGE PERCENTAGE COMPOSITION.

Organic matter,	15.00	14.19	1867	Dr. Letheby.
Mineral	85.00	85.81	1868	"
	100.00	100.00		

\* "Report upon the Discharge of Metropolitan Sewage into the River Thames at Barking Creek and Crossness." By Capt. E. R. Calver, R.N., F.R.S.

On these analyses Dr. Letheby remarks that the above percentage proportions did not differ materially from the quantities of organic and sewage matters which he found suspended in water at London Bridge, and in the mud at London Bridge, Chelsea, and Westminster, when the sewage was discharged at low water. The next table gives nearly identical results from the analysis of the mud at the outfalls in 1867, and those of the suspended matter in the Thames water at Greenwich, Woolwich, and London Bridge in 1862, by the same chemist. Now, Dr. W. A. Miller so far agrees with these results that in his evidence, given at the inquiry before referred to, in 1869, he states the percentage of organic matter in the mud taken from Barking Creek to be 16.2, from the Thames between Chiswick and Westminster, 15.8, and further, that of these two quantities 3.1 and 3.05 respectively consists of nitrogen, and finally, in answer to the question: "But there is nothing special and differing in the mud at Barking from the ordinary mud of the River Thames?" he says: No, the composition is as nearly the same as may be. With these observations Dr. Odling's evidence closely agrees.

Here, then, we have an agreement which nobody appears to dispute, and which leads inevitably to the conclusion that the great bulk of noxious putrescible matter left uncovered at low water throughout the whole of the tidal portion of the Thames owes its deleterious character mainly, if not entirely, to the presence of sewage matters. Having carefully pointed out and established this identity of composition, Capt. Calver proceeds: "It is, however, equally necessary to prove that there is enough of this material in the sewage discharged from the outfalls to account for the large accumulations of it which have found a resting-place in the Thames channel." Here we are met by estimates differing in the wildest manner, and varying from 35 to 100 grains per gallon, and again to nearly double that amount, but fortunately we are here even given material for a trustworthy estimate. In the table of analysis given by Prof. Williamson of samples taken from the northern outfall in September of this year we find 108.01 and 151.45 grains per gallon as the actual

amount of suspended solid matter at different times, the samples being collected in fine weather. Now abundant evidence has been given at various times, showing that after heavy rain the sewage contains an amount of solid impurity equal to, if not greater than, that in the fine-weather flow; thus there can be no doubt that the lower of these two figures is not in excess of the average. Capt. Calver takes the amount at 100 grains per gallon, and multiplying by the daily discharge, quoted as 120 million gallons, he obtains a result of 279,225 tons per annum. This probably does not exceed one-half the true amount, as the water supply of the metropolis alone reaches the amount assumed for the daily discharge, and the rainfall over the drainage area gives nearly an equal amount, which, for the reason just stated, must be taken into account. We thus appear to have at command upwards of half a million tons of suspended matter discharged into the Thames in each year, which is amply sufficient to account for the deposits observed. Thus we read in the report that "Mr. Leach (the engineer of the Thames Conservancy Board) reported in December (1871) that a deposition of 7 feet 9 inches of mud had formed between the upper end of the southern embankment and the White Hart Draw Dock, Lambeth; that another bank, 100 feet wide and 6 feet thick, occupied the river-frontage of St. Thomas's Hospital, &c. By July of last year a material portion of these masses had been cleared away by excessive rainfalls." Are we to be left to the mercy of such an unpleasant remedy as the floods of last autumn to abate a nuisance of such magnitude, threatening, as it does, the existence of such an institution as St. Thomas's Hospital, and showing how soon we may return to the unsanitary state of affairs that existed twenty-five years ago? We have purposely avoided dealing with an equally important part of Capt. Calver's report, in which he points out the danger of the silting up of the navigable channel of the Thames below London, as he has not shown that the sectional area, though varying from year to year, has at any point permanently diminished, still the destructive elements have been shown to exist, and the forces which now hold them in equi-

librium may at any time be thrown out of balance and the evil creep on imperceptibly, if once the eyes of the public are closed to its existence. Without going into the question of the value of the sewage estimated by the highest authorities at £1,000,000 per annum, thus not only wasted but employed as a powerful obnoxious agent, enough has been shown from the report before us to, we hope, show the suicidal folly of discharging sewage wholesale and unpurified into tidal rivers. Yet even now a scheme is under consideration for the collection of the sewage from a large area in the Thames Valley and for its discharge into the tidal waters of the Thames. We believe that a careful perusal of Capt. Calver's Report will dispel from the minds of the Thames Valley Joint Board all hopes of a satisfactory though expensive solution of their difficult problem being arrived at in this manner. As a remedy for the state of things he has shown to exist Capt. Calver recommends that, in pursuance of the powers they possess, the Conservancy Board call upon the Metropolitan Board to dredge away the obstructions they have caused; this may be

indispensable at present, and may be an unavoidable and constantly recurring expense until some profitable scheme is devised for utilizing the metropolitan sewage; in the meanwhile the example of the inhabitants of Abingdon, as shown by the letter of their medical officer of health in the *Sanitary Record* of November 30, shows the inutility of other towns in the valley of the Thames striving to follow the example of London, and further increasing its difficulties. We learn from Dr. Woodforde's letter that the whole of the sewage of the town of Abingdon is purified by filtration through natural soil being frequently absorbed by one acre of land, and that the amount of organic and inorganic impurity contained in the effluent water after passing through the land is far less, in some cases less than one-half that contained in the well water used for drinking purposes in the town. As this unprecedented result has been obtained on land of a character which exists in abundance throughout the Valley of the Thames we think that the towns situated therein have not far to look for the solution of their difficulties.

## PRESSURE ON FOUNDATIONS.

From "The Engineer."

When an engineer is called upon to design any structure of importance, a part of which has to be constructed below the natural surface of the ground, his first question is, "What sort of a foundation is there?" The character of the superstructure may be to a great extent a matter of choice, and, in some instances, may be varied almost at pleasure; but the nature of the substratum is fixed unalterably, and there is no escape from any difficulties which it may entail, except, indeed, as rarely occurs, when a change of site is possible. The most essential preliminary operation towards ascertaining the description of soil upon which one has to build is that of boring, and it is truly surprising how frequently it is neglected. In numerous instances which we could mention where the works have been of considerable magni-

tude, there were either no borings whatever made, or those that were made were sunk at intervals so few and so far between as to afford no accurate indication of the real nature of the subsoil, and the pressure which it might be safely assumed to bear. At the present moment there is a large building in the metropolis, the progress of which is completely arrested, owing to the fact that the money intended for the superstructure has been absorbed in the foundations. It might reasonably be supposed that if an adequate number of borings had been made, they would have revealed the true character of the sub-stratum, and enabled a correct estimate of the necessary depth and cost of the foundation to be made.

The pressure upon foundations may be divided into two separate heads—first, the total pressure due to the weight

of the building, and, secondly, the greatest pressure upon a unit of area. The latter consideration, in conjunction with the bearing capabilities of the ground, usually determines the general character of the sub-structure, and the mode in which it is designed and arranged. It does not, however, necessarily follow that the harder and more unyielding the ground, the better it is adapted as a foundation for structures in which there is a great localization of pressure. There are circumstances in which adamant itself would present greater difficulties in this respect than shifting sands. A rock foundation, of a homogeneous consistency, might possibly be safely loaded with any weight short of its own crushing load; but a foundation of this description is not by any means a universal desideratum with engineers. Consequently the mere power of bearing great pressure is not the sole requisite to be looked for in searching for a good foundation. A very important feature with regard to founding a structure securely is the possibility of penetrating to a certain depth into the stratum in which the foundations are to be laid. It is obvious that, viewed in this light, the harder the stratum the greater the difficulty and the expense of founding the building. Although the possibility of rock carrying safely a load nearly equal to its own crushing weight has been mentioned, yet in practice it would not be assumed to bear more than a sixth, or even an eighth of this amount.

Rock which is not of a homogeneous texture, or which will not bear exposure to the air, or which comes under the denomination of "bad rock," constitutes a very undesirable stratum upon which to build. It is suitable neither for diffused nor concentrated pressure. Its bearing capacity is very limited, while its hardness renders it generally difficult of penetration, although there may be "soft spots" here and there. The usual practice in cases in which this want of uniformity in the resistance of the ground exists, and in which the pressure is diffused, is to lay a bottom course of concrete over the whole foundation area and build upon it. In adopting this method the precaution must be taken of giving the concrete a sufficient minimum

thickness, or the result will be that the concrete will crack first and the building afterwards. It is for this reason that it is often preferable, especially if the area of surface bears a large proportion to the cubic contents, to employ bituminous concrete, or concrete of a composition which insures some slight amount of elasticity throughout it. It is evident that the pressure of any structure, whatever its total weight might amount to, would, when uniformly diffused over solid rock, be trifling compared to the almost unlimited resisting powers of the rock itself. If we accept concentrated loads, such as those transmitted through piles and columns, the pressure exercised by the Britannia tower in the Menai Straits upon the rock at its base may be considered as one example of the greatest pressure upon a foundation of this nature. What does it amount to? It equals sixteen tons to the square foot, or only about one-thirtieth of the absolute crushing weight of the stone of which the tower itself is built. For a choice of foundation we should prefer under ordinary circumstances a substratum of hard compact gravel to any other.

There is a very large class of engineering structures which cannot be founded on a wide or extended area of base. In their case the supports of the super-structure must be at considerable intervals of space. This class comprises such work as bridges over rivers and estuaries, as built according to modern practice, piers and jetties, roofs of large stations and manufactories, and all public buildings in which the area under cover is so large as to necessitate the employment of columns and pillars in order to subdivide the total span from side wall to side wall. The concentration of weight thus thrown upon single pillars nevertheless rarely reaches the amount attained by the more solid and massive types of construction. From seven to eight tons per square foot appear to constitute the greatest pressure exercised upon the foundation, by the best known examples of the class of engineering works referred to. This apparent anomaly is unquestionably due—in the case of bridges at least—to the great difference in the dead weight of the old and modern structures themselves respectively, and not to the

live or rolling load which they were intended to carry. As an example, compare Waterloo Bridge with the Charing Cross Railway Bridge, both of which are founded upon the same bottom; the dead weight of the former is enormously in excess of that of the latter. But when the moving load is considered the proportion becomes reversed. Waterloo Bridge was never intended to carry four lines of running locomotives on it, and probably never will, although there is no doubt it could do so with perfect safety. This is more than could be said of either Westminster or Blackfriars Bridge. The cylindrical foundations of Charing Cross Railway Bridge are carried down to a considerably greater depth than the rectangular piers of the stone bridge, and consequently derive great additional support from the lateral pressure or friction of the ground into which they penetrate.

The question then arises, in what proportion does this augment the resistance to a concentrated load, as compared with the same load diffused over a larger foundation, which, owing to its particular form and shallowness of penetration, gains practically little or no advantage from any lateral pressure or friction? In other words, to what depth should a cylinder of a given area be sunk, in order that the form of the vertical and lateral or frictional resistances should be equal to the vertical reaction of a given rectangular area which receives no frictional resistance? Having regard solely to the foundations of the two structures, and assuming their weights to be equal, suppose Charing Cross Bridge were piled up on Waterloo Bridge, would the latter be able to carry it? We think it would. On the other hand, suppose Waterloo Bridge were super-imposed upon that at Charing Cross, would the latter be able to support it? We think not.

The pressure brought in some few instances upon timber piles must be regarded as exceptions to the statement previously made, that concentrated loads rarely attained to the same amount as those of a diffusive character, provided that it be conceded that the loads in question were carried exclusively by the piles. This is very doubtful indeed, as it is impossible to exclude from considera-

tion the resisting action of the surrounding ground. Besides, in numerous instances timber piles are driven quite as much with the view of consolidating, and thus increasing the supporting power of the soil, as with the intention of carrying much pressure themselves. When the substratum consists of sand or good clay, disc and screw piles are very much used by engineers for supporting concentrated loads, especially when the structure is erected over a river or in the sea. Modern examples of this class of engineering works give from four to seven tons as a safe practical pressure per square foot of either disc or screw blade of the pile. It is equally uncertain in this instance what amount of resistance is derived from friction; probably not so much as in the case of piles and cylinders of a uniform diameter without discs or blades, because although the earth closes round the shaft of the latter description of piles, yet it may not possess quite the same resistance as if it had never been disturbed. It is found in screwing piles into clay that the clay does not rise in the interior of the pile to the same level which it has on the outside, although a column of it equal to that height must have been displaced by the sinking of the pile.

In conclusion, we will cite a very recent example of the uncertainty which exists with respect to foundations and the pressure which the soil will bear. It occurred in connection with the building of a large underground tank. A similar tank, about 40 feet or 50 feet from the site of the new one had been in existence for several years, and never evinced any sign of failure or weakness. Its foundation had been proved by borings to be of an excellent character. When the new tank was nearly completed some very heavy rains came on, and in one night the outside slopes fell in and the bottom of the tank "blew up," as it is termed, breaking the piles, walings, and other large timbers into pieces. An examination of the ground and subsequent borings showed this particular spot of so limited an area, to have such a bad bottom, that it was found preferable to choose a fresh site close to the other, and build another tank, rather than attempt to repair that nearly destroyed.

## EXPERIMENTS ON THE STEAM ENGINE.

By G. A. HIRN, DWELSHAUVERS-DERY, W. GROSSETESTE AND O. HALLAUER.

From "Bulletin spécial de la Société de Mulhouse," Abstracts published for the Institution of Civil Engineers.

THESE experiments were made according to the analytical and experimental method developed in the second volume of M. Hirn's recent work on Thermodynamics. They show that the steam-engine cannot be considered as a simple mechanism, of which the functions may be analyzed without reference to the physical properties of the organs, but that the surface of the cylinders act as thermic reservoirs, which absorb and give up heat alternately to the steam during its working and ejection. Errors, not of 2 or 3 per cent., as anticipated, but of 40 and 50 per cent., are thus caused between estimated and actual result. As an instance, steam superheated to 446° Fahr., in which condition it may almost be considered a permanent gas, falls on entering the cylinder to its point of saturation, and even condenses in part. This is discouraging, because it shows how difficult it is to form a general theory of the steam-engine, how an improvement in one direction is counteracted in another, while it explains the frequently vast difference between theory and practice. The experiments were made specially with the intention of discovering what amount of expansion of steam gives the maximum economy with a certain pressure and a certain amount of superheating; also the difference between a condensing and a high-pressure engine.

In order that a body after being expanded through heat may perform external work, it must be cooled, and thermodynamics teach the simple relation which exists between the maximum work obtained, the quantity of heat furnished, and the absolute temperatures between which the operations are performed—the range. The maximum temperature even for superheated steam must be below that at which lubricating materials are decomposed, or about 482° Fahr., while condensing water cannot be relied on below 68°, so that the maximum of possible effect is 249 French HP. per 100 calories expended, nearly 250 HP. per 400 British thermal units.

The machine employed was a beam engine, with a single vertical cylinder, furnished with four distributing valves, and supplied sometimes with saturated and sometimes with superheated steam.

In one instance it worked at high pressure without a condenser; the expansion could be varied at will. The observations made may be grouped in three separate series:

I. The weight of steam consumed, and of hot water ejected from the condenser, obtained by two distinct gaugings, the difference being the injection water. The feed-pump drew the boiler supply from a cask alternately filled and emptied, and the ejection water from the condenser was received into a masonry tank, and, flowing through an orifice in a thin partition, was deduced from the mean of the day's quantities above the orifice. A table gives the date of observation, the extent to which the steam was superheated, the cut-off, the weight of steam and that of the injected water per piston stroke.

II. The temperatures of the injection and ejection water were observed, and are given in a second table.

III. Estimate of the details of the work. Under this heading were considered not only the full pressure, expansion, and counter-pressure, and the real indicated effect, but also the pressures at different points in the cylinder, where it is wished to study the heat state of the steam. M. Regnault's tables give all the data, such as the temperature, density, total heat of evaporation, and the internal heat of the steam, whilst the pressure at each moment was obtained by M. Hirn's flexion Pandynamometer, which utilizes the beam of an engine as a spring, and measures its deflection. A third table gives the indicated HP. and revolutions per minute thus obtained. In a fourth table are shown the mean boiler pressure, and the temperature of the steam generated, as indicated by an open-air manometer, together with the values which lead to the first verification; that of the consumption of the

motor per piston stroke for the calories produced by the steam, diminished by those absorbed in work and external cooling, must be found in the condensation water. The results obtained are, with one exception, correct within 1 per cent.; the cause of the error of 3 per cent. in the excepted case cannot be traced.

Influence of the surface of the cylinders. Extent of the error which may be committed in neglecting their action. For this purpose it is necessary to calculate the weight of steam used at various points of the course of the piston. The volumes generated by the piston are obtained by direct measurement; the pressures, for instance, at the commencement of the expansion and at the end of the stroke give the corresponding values of the densities of dry steam, and it is quite easy to obtain the weight of vapor present at these two points. The difference between the weight of vapor directly gauged and that equivalent to the commencement of the expansion and end of the stroke, as given in a fifth table, is generally a loss, but sometimes a gain.

The loss was at first attributed to an escape between the piston and cylinder, but this would not explain the case when the calculated was in excess of the measured weight; the piston may then be considered hermetical, and the key to the loss is derived from the same proposition of physics from which Watt derived the theory of the condenser, viz., that when steam is introduced into a reservoir of invariable dimensions, whose walls are not all of the same temperature, the final tension is always that which corresponds to the lowest temperature.

When the steam is taken direct from the boiler, it is a saturated vapor of which a portion condenses on the slightest fall of temperature, and as the steam generally carries a portion of water with it, an addition of heat vaporizes this water. The steam enters the cylinder, the surfaces of which are of a lower temperature than itself, and of considerable extent relative to its volume. The steam condenses, giving up to the metal its heat of evaporation; the piston moves slowly at first, and then more quickly, offering new and increased surfaces to condense the steam; the valve

closes, the expansion begins; without interrupting the exchanges of heat between the originally heated and the cold part of the cylinder, the steam and its liquid evaporate on one part and condense on another, until at the end of the stroke the steam is in a condition different from that existing at the end of the admission. The same changes take place with superheated vapor, which loses not only the superheat, but a portion of its heat of evaporation, and condenses.

Hitherto this loss of heat has certainly not been denied, but its effect has been considered insignificant, for the reason that gases are bad heat-conductors, and the time of a piston stroke has been considered too short to allow of a considerable exchange of heat by radiation; this, however, takes place by direct contact and condensation, not by radiation, and produced a condensation in one case as high as 36 per cent. at the commencement of the expansion. In certain cases very slight quantities of water have been found: thus with superheated steam, and a cut-off of  $\frac{1}{5}$ ,  $\frac{1}{2}$ , the condensation has been only 1,  $2\frac{1}{2}$  per cent., whilst with saturated vapor, and a cut-off of  $\frac{1}{4}$ , there have been condensations of 25 to 36 per cent. M. Hirn explains this by assuming that in the interior of the mass, and notwithstanding the condensation which always takes place on the metal, the steam remains superheated at a temperature superior to the tension reached.

The next question is what becomes of the heat in the cylinder sides, and it is necessary to define the internal heat (U) of a mixture of steam and water: it is the total heat of the mixture, diminished by the portion which the external work has cost. To know what takes place in expansion, it is necessary to compare the internal initial and final heat, as well as the amount absorbed in the interval, by the work of expansion. This comparison is made in Table 6, in which in two cases the internal heat is greater at the end of the stroke than at the commencement of the expansion, and yet the work of expansion has caused a disappearance of heat, and the gain of heat must have been at the expense of the cylinder walls. But this is only one side of the question, for the cylinder walls contain

more heat than they have given up, and the remainder has to be accounted for. It is the so-called *R c* cooling at the condenser, and is a loss caused as follows: When the moment of release arrives, the valve opens to the condenser, the pressure rapidly falls to that corresponding to the temperature of the condenser, and is less than that of the end of the stroke; the temperature of the cylinder sides is greater than that corresponding to the pressure; evaporation and boiling occur, and a quantity of heat is sent to the condenser without producing any useful effect. To recapitulate, *R c* is the heat taken from the cylinder sides during the release, increased by that of the work of ejection; it should be found *in toto* in the condensation water. On the other hand, being in the cylinder sides, it does not figure in the expression for the final internal heat *U*; the difference between these quantities gives it. A Table contains this comparison, the greatest ratio of difference being about 1 per cent. The only case in which *R c* was a negative quantity was in the high-pressure trial, in which the steam was found dry at the end of the stroke. This is a thorough confirmation of the reason assigned for the loss in other cases; a loss

amounting to as much as 22 per cent., and one that should, if possible, be reduced.

To show how the errors committed on the expenditure of steam may extend to the estimate of the work, it should be ascertained whether the steam condensed during the admission really corresponds, 1st, to the work produced by expansion; 2nd, to the external cooling of the cylinder; 3rd, to the internal cooling of the cylinder whilst the steam is injected into the condenser. M. Hirn has done this by considering the active portion of the sides of the cylinder to form, as it were, part of the steam and water present, and to have their temperature; and he has thus obtained an integral of all the quantities which enter into the question, viz., the mass of steam, the absolute temperature, the heat of evaporation and the capacity, which is compared with the value taken directly from the curves, showing an accordance to within 1 per cent. Another table gives the proportion of vesicular water either attached to the sides, or in suspension in the steam and carried to the condenser. The direct practical consequences of the experiments are next considered, and the following recapitulatory table is given:

Date of Trial.	State of Steam.	Pressure of Steam at end of admission. Per sq. inch.	Work in HP.	Consumption of Steam per 1 HP. per Hour.	Proportion of Water at end of Stroke.	Proportion of Heat carried off by Re.
Nov. 18, 1873	{ Steam superheated 447.8° F. (231° C.) Admission $\frac{1}{4}$	56.248 lbs.	144.36	16.902 lbs.	Percent. 12.0	Percent. 7.8
Nov. 28, 1873	{ Saturated Steam Admission $\frac{1}{4}$	53.724 lbs.	136.46	22.057 lbs.	25.2	15.6
Aug. 26, 1875	{ Steam superheated 419° F. (215° C.) Admission $\frac{1}{2}$	58.904 lbs.	135.77	15.404 lbs.	17.5	9.7
Aug. 27, 1875	{ Steam superheated 433.4° F. (223° C.) Admission $\frac{1}{2}$ , valve partly closed	32.802 lbs.	125.17	18.037 lbs.	13.2	10.5
Sept. 7, 1875	{ Steam superheated 383° F. (195° C.) Admission $\frac{1}{4}$	55.651 lbs.	113.08	15.677 lbs.	21.38	12.43
Sept. 8, 1875	{ Saturated steam Admission $\frac{1}{4}$	54.529 lbs.	107.81	19.613 lbs.	35.19	21.76
Sept. 29, 1875	{ Steam superheated 425° F. (220° C.) Admission $\frac{1}{2}$ , valve more closed	24.830 lbs.	99.53	18.099 lbs.	15.85	14.21
Oct. 28, 1875	{ Steam superheated 428° F. (220° C.) Admission $\frac{1}{4}$ , without condensation	48.831 lbs.	78.30	27.093 lbs.	0.00	0.00

In comparing the results of 1873 and 1875 under similar conditions, there are anomalies explained by the cylinder having been altered, the exhaust ports increased, and the lead made greater, which improvements have caused a diminution of 10 per cent. in steam consumption. The question of superheating is not further discussed, as it is shown to give an economy of 20 per cent.; but in conclusion the three following matters are considered:

1. The influence of expansion. Admissions varying from  $\frac{1}{4}$  to  $\frac{1}{2}$  give about the same consumption; these obtain in practice. Below  $\frac{1}{4}$ , water at the end of the stroke and R c increase, and hence a point would be arrived at when the engine would be less economical, which has not, however, been discovered by the Author. On the other hand, an admission of  $\frac{1}{2}$  has been clearly shown to give larger expenditure.

2. The influence of wire-drawing the steam. Two experiments show that this is without effect on the economy; the steam was superheated in each case equally (see 27th Aug. and 29th Sept. in the table), and there was a difference of  $\frac{1}{2}$  atmosphere of pressure, but the consumption of steam remained the same. The difference between the results of the 26 and 27 Aug. is due to difference of expansion and not to wire-drawing.

3. Economy realized by application of the condenser. This is shown to be at least 43 per cent.

In the commencement it was stated that 249 HP. per 100 calories is the theoretical maximum, with a limit of temperature of 482° Fahr. The highest result obtained in these experiments is 135.77 HP. per 172.79 calories, or 31.5 per cent.

#### REPORTS OF ENGINEERING SOCIETIES.

**ENGINEERS' CLUB OF PHILADELPHIA.**—At the last meeting of this society eleven new members were elected. Mr. J. F. Robinson read a paper on "Steam Motors and Cars for Street Railways," in which he gave an interesting account of their manufacture, giving dimensions, weight, tractive power, &c. Steam Cars with 7 feet wheel base, as at present built at the Baldwin Locomotive works, have been successfully used on roads having curves as short as 25 feet radius and grades as high as 369 feet to the mile. Mr. Robinson also said the comparative expense of operating roads by means of horses or steam motors proves to be in favor

of the latter. Mr. George Burnham Jr., read a short paper on the "Stow Flexible Shafting." The largest-sized shafting at present manufactured is  $1\frac{1}{4}$  inches in diameter, with which a power of 60,000 pounds, or more than 2 horse power, can be transmitted. Mr. Charles A. Ashburner read brief articles on the "South Street Bridge," "The Metric System" and "The Jetty Question." The papers were illustrated by models, photographs and working drawings.—*From the Philadelphia Ledger, February 6th, 1878.*

At a meeting held on Monday, December 17, 1877, the following gentlemen were elected to serve as officers for 1878: President, Professor Lewis M. Haupt; Vice-President, Coleman Sellers, Jr.; Secretary and Treasurer, Charles E. Billin.

#### CIVIL AND MECHANICAL ENGINEERS' SOCIETY.

—At a meeting in January a paper "On House Drainage" was read by Mr. H. T. Munday, A. I. C. E., before the Civil and Mechanical Engineers' Society, at 7, Westminster-chambers, Mr. H. V. F. Valpy, the president in the chair. The Author described the present defective system which existed in nearly every house, and showed how, both in execution and design, the principles of sanitary science are habitually ignored. Descriptions were given of several different methods of house drainage, either patented or carried out by those who have made this subject their special study. Some of these systems were illustrated by diagrams, and their merits and defects were pointed out. Especial reference was made to the plans adopted by Messrs. Osborne, Reynolds, Buchan, Banner, and Rogers Field. In the opinion of the author, Mr. Field had been the most successful in dealing with the difficulties of the questions. Some of the principles which ought to underlie any methods of house drainage aiming at satisfactory results were expounded, and it was stated that although alterations to old houses might be costly, the money spent for this object could not be considered as wasted by householders who had any regard for cleanliness and health. Every one owning or leasing a house should examine its system of drainage carefully, and in most cases they would be speedily convinced of the necessity for a radical alteration. An animated discussion ensued in which Messrs. Eachus, Payne, Street, Burrell, Brewer, and the president took part, and a unanimous vote of thanks for the paper was passed to Mr. Munday. The meeting then adjourned till January 24th, when a paper will be read "On Chimney Shafts," by Mr. R. M. Bancroft.

**LIVERPOOL ENGINEERING SOCIETY.**—At a late meeting of this society the attention of the meeting was called by Mr. Graham Smith, past president, to a peculiar method of making the foundations of wooden pavements with sand in place of concrete. The sand is laid to a depth of 6 inches on the surface of the ground, then rolled and rammed, and on this the blocks are laid, and wedges driven between them into the sand about 5 inches or 6 inches. This system is largely employed in America, especially in New York and San Francisco,

and is said to give every satisfaction, so that we may hope Mr. Charles Green's—Gresham House, E.C.—efforts to introduce it into this country will meet with a favorable reception. Mr. Wüfred S. Boulton, member, then read a paper on "Portland Cement Concrete." After enumerating the advantage of employing concrete in the place of brickwork or stone, in certain positions, he said he considered a *prima facie* case made out in its favor wherever there happened to be large spoil-heaps of rock rubbish or considerable deposits of shingle or gravel. For tide work, he considered concrete blocks to have a decided advantage over its rivals, on account of the rapidity with which the blocks, when formed, can be set in place. From his own experience, Mr. Boulton said he had known of as many as forty-five 7-ton blocks being set in one tide, by one setting gang, with the aid of a steam jenny. He considered that in order to get good concrete great care should be taken to have a proper gradation in the sizes of the stones and materials used as aggregates. When speaking of the strength of Portland cement, he mentioned that the specifications of Mr. Deacon, borough engineer, required 800 pounds, and that of Mr. Lyster, the dock engineer 700 pounds per 2½ square inch testing section. The paper was well illustrated by numerous diagrams and photographs of machinery employed in mixing concrete, and in constructing concrete works, which the author described in detail. After describing the construction of a concrete graving dock, 950 feet in length, with which he had been connected, and the machinery employed, he concluded by giving many statistics of the actual cost of concrete work. From these we gather that the cost of labor in making concrete blocks in large quantities amounts to only 2s. 7d. per cubic yard.

**INSTITUTION OF CIVIL ENGINEERS—THE PRESIDENT'S ADDRESS.** The first meeting after the Christmas recess was held on Tuesday, the 15th of January, when the newly-elected president, Mr. John Frederic Bateman, delivered an inaugural address.

After a passing allusion to the growth of the Institution, which at the end of 1844 numbered only 552 of all classes, now increased to 3,189, reference was made to some of the addresses of the eighteen gentlemen who had previously occupied the presidential chair, mainly for the purposes of comparison. Thus, Mr. Robert Stephenson, in summarising the statistics of British railways to the end of 1854, mentioned that 368 millions sterling had been authorized to be expended, of which 286 millions had been raised, whereas at the end of 1876 these figures were respectively 742 and 682 millions. Again, Mr. Locke, in treating of French railways, remarked that at the close of 1856 concessions had been granted for 7,030 miles, of which 4,060 miles were open: whilst at the close of 1876 these mileages were 16,452 and 12,715. Mr. McClean had contrasted the income available for taxation in 1815 with 1856, and had shown that in the interval the revenue from land had not increased, while that from houses had augmented 300 per cent., and from quarries,

mines, ironworks, canals, railways &c., 1,200 per cent. There was evidence that since 1856 the increase had been very great, even if these high rates had not actually been maintained. These remarks showed how largely the engineer had been employed, and how much his labors had contributed to the development of the wealth and prosperity of all countries where he had been engaged.

Proceeding to matters more personal to every member of the Institution the president urged that engineering was but, in fact, the embodiment of practical wisdom; or in the words of Bacon, "the conjunction of contemplation and action." Thought, combined with practice, had led to the perfection of the steam engine by James Watt, to the successful application of the locomotive engine by George Stephenson, and to the production of the electric telegraph. It was to the combination of sound theory with successful practice that engineering owed its present position, and had been able to advance material prosperity. It might, however, lay claim to more than that, for the works of the engineer had carried the blessings of civilization into every quarter of the globe; the steam-engine in its various applications had knitted together the most distant nations; ignorance had been brought into contact with knowledge, and heathenism with Christianity. On these grounds, and on others, the education of the engineer was of serious moment. In France, and on the continent generally, where public works were mainly carried out by the governments, engineers were educated in special schools, the theoretical information thus acquired being admittedly superior, as a rule, to that imparted in this country; yet the students lack that practical experience which had hitherto been the main source of the success of the English engineer, who owed little or nothing to government patronage, and whose employment depended on individual merit, the works being undertaken by private enterprise. Still our young engineers were not always prepared, by preliminary education, as well as they might be, for the subsequent acquisition of practical knowledge. Special qualifications, and some of a high order, were required; and it would be well if advantage were taken of the numerous public schools in which instruction bearing on engineering was given, with a view to prevent young men becoming pupils without these qualifications. But it must be understood that such training could only be regarded as preparatory, and not as being complete in itself, and it was a mistake and mischievous where any college or school professed to fit a student to act at once as an engineer.

The President then gave a brief description of a few of the principal engineering works recently completed, or at present under construction; mentioning in telegraph engineering the telephones of Mr. A. G. Bell and Mr. Edison, instruments which differed in construction, but by both of which the human voice, with all its modulations, could be transmitted to great distances. Then, again, the quadruple system of telegraphy, imported from America, had also come into use. By this system two messages

could be sent in each direction by the same wire at the same time. During the past year electricity had put forward other claims than those relating to means of communication. Thus, the electric light, if it could not at present compete successfully with the convenience in domestic arrangements of gas lighting, had been found useful and effective for the illumination of large spaces, and the invention was about to be applied at the Lizard Point Light-houses.

In the conviction that experience of a special kind, gained during a long professional life, was of more real value than allusions, however lucid, to a variety of subjects, the president next adverted to a question which was of the highest importance in that branch of the profession to which his attention had been more particularly directed, viz.:—the rainfall of this country, and the quantity of water which flowed off the ground, available for the use of man if properly utilized, or destructive when uncontrolled and permitted to cause floods or torrents.

### IRON AND STEEL NOTES.

A LARGE shipment of Tasmanian pig iron was, according to the *Iron and Coal Trades Review*, received in London, a short time ago, by Messrs. James M'Ewen and Co., the object of the Tasmanian shippers being to ascertain the precise value of their product among the practical ironworkers in England. Dr. Siemens has used seventy tons of the pig iron for conversion into octagon steel, and a shipment of the article produced was sent out to the colony by the Whampoa on the 24th ult. Dr. Siemens speaks in very flattering terms of its quality. The pig iron is of a peculiar nature, in consequence of the presence in it of the rare metal rhodium, but whether this is an advance or a drawback time will tell. Six hundred tons of the pig iron are now in the hands of Sheffield manufacturers, so that its good or bad qualities will be put to a searching test. It is not to be expected that any of the iron or steel will ever find its way into the English market as an article of trade, but if the Australian demand is supplied from the Tasmanian mines, the English market will be affected to the extent of the diminished export.

M. M. TROOST AND HAUTEFEUILLE recently showed that small quantities of sulphur or phosphorus combined with iron do not destroy its metallic lustre, but alter its malleability and ductility considerably. The sulphuretted and phosphuretted iron, which cannot be considered as sulphides and phosphides, act quite differently when considered thermometrically. Two kinds of sulphuretted iron, one with 1.8 per cent. of sulphur, the other with 5.4 per cent., when treated with moist mercuric chloride, evolved respectively 810 and 840 units of heat per gramme. The metal with 1.8 per cent. of sulphur, which is quite considerable from a point of view, evolved the same quantity of heat as pure iron, while the other with 5.4 per cent. sulphur evolved more

heat than the latter. Iron containing phosphorus acts totally different. Two samples of iron, containing respectively five and ten per cent. of phosphorus, when treated with mercuric chloride, evolved 790 and 410 equivalents of heat per gramme. From this it is evident that the combination of iron with phosphorus takes place with a great evolution of heat, and that a permanent chemical compound is formed. The sulphuretted iron is comparable to the silicuretted iron, which is formed with scarcely any evolution of heat. We know, too, that sulphur is far more easily eliminated from iron than phosphorus. The sulphur and phosphorus compounds of manganese, prepared from manganese that contains carbon, are attacked with difficulty by moist mercuric chloride, which is a sign that they are formed with a great evolution of heat, and are therefore more stable compounds than the corresponding iron compounds.

THE results of experiments upon the thermic relations of iron and manganese compounds, made by MM. Troost and Hautefeuille, leads to the conclusion that the manganese used in treating impure iron forms with the foreign substances compounds which are dissolved in and distributed through the mass of metal, and they render purification easier because they impart to the elements which are to be eliminated the oxidizability of the corresponding manganese compounds. At all events, this is frequently the case: but the manganese also plays another and simpler part, namely, it acts at the same time as the reducer of the oxide of iron. In different metallurgical operations the elimination of the sulphur and phosphorus, if carried far enough, requires a long protracted oxidation, which produces an iron which contains oxide of iron. By adding ferro-manganese, which is always rich in carbon, the necessary amount of carbon is added to the iron, and at the same time the oxide of iron is reduced with an evolution of heat, both by the carbon and the manganese. The oxide of manganese produced is distributed through the metal, but does not impart to it the injurious properties that oxide of iron would, for it passes almost completely into the slag and takes the impurities with it. Hence, whether the manganese is already in the metal to be purified, or is added during the refining, its importance always consists, first, in the formation of compounds, the formation of which is accompanied by more evolution of heat than the corresponding iron compounds, and second, in the ease with which these compounds go into the slag, because they oxidize with the evolution of more heat than those which contain equal quantity of iron, especially when they are mixed with a large quantity of the metal in excess.—*Engineering*.

### RAILWAY NOTES.

RAILROAD CONSTRUCTION IN 1877.—Our annual record of the construction of railroads in the United States, published this week shows that 2,199 miles were completed in 1877,

against 2,460 in 1876, 1,561 in 1875, 2,025 in 1874, 3,883 in 1873, and 7,340 in 1872. The decrease as compared with 1876 is nearly 11 per cent., but the total is above the average since the panic of 1873, that average for the four years having been 2,061 miles. Neither is it a small amount of work in comparison with the population and traffic of the country and their rate of growth. The increase in the railroad mileage is about as great as the average increase of population in the country, and this country has long had a larger mileage in proportion to the population than any other civilized nation. We have now very nearly 80,000 miles of railroad in the country, with a probable population of 45,800,000. This gives 575 people to support one mile of railroad, and a nominal investment in railroads of about \$100 per individual.

Now Europe has about 3,310 inhabitants to support one mile of railroad, or nearly six times as many as this country, and in Great Britain and Belgium—where the country is most fully provided with railroads—there are 1,860 and 2,283 inhabitants, respectively, per mile. So far as population is concerned, therefore, this country is already exceptionally well provided.

We have noticed that the construction since 1873 has been chiefly of short lines of local interest. This was especially true in 1877. The number of lines was greater than before since 1873, and the average length of each line has been smaller but once, as will appear from the following:

Year.	No. of companies.	Total Built.	Average length.
1872.....	210	7,340	35.0
1873.....	137	3,883	28.3
1874.....	105	2,025	19.3
1875.....	94	1,561	16.6
1876.....	107	2,460	23.0
1877.....	117	2,199	18.8

Indeed there were very few lines constructed in 1877 which can be called long. The longest single line was the 120 miles of the Southern Pacific extension: then follow the Minneapolis & St Louis, 91 miles; the Colorado Central, 70 miles; the Rochester & State Line, 68 miles; the Maple river, 59 miles; the Syracuse, Geneva & Corning, 56 miles; and the Philadelphia & Atlantic City, 54 miles. No other line as much as 50 miles long was constructed during the year.

These seven companies constructed 518 miles of the total year, so that the average length of the other lines was but 15 miles. In 1876 there were five companies which constructed more than a hundred miles apiece, and the eight which constructed 50 miles or more apiece built an aggregate of 898 miles; or 36 per cent. of the total.

About two-thirds of the total mileage built last year (1,418 miles) was in eight States, each of which constructed more than 100 miles. The States with largest mileage for two years past are:

1877	
California.....	239
Ohio.....	236

Minnesota.....	210
Texas.....	169
New York.....	152
Iowa.....	150
Pennsylvania.....	143
Colorado.....	119

## 1876

Texas.....	388
California.....	350
Ohio.....	270
Colorado.....	155
Kentucky.....	138
Wisconsin.....	124
Missouri.....	109

The most interesting comparison is that of groups of States. In 1873 and previous the great field of railroad construction was in the upper Mississippi valley, generally known as the "Northwest," and so called in our grouping above. In 1872 43 per cent. of the total new roads was in that section; in 1873 nearly 30 per cent. In 1874 this fell to 25 per cent; in 1875 to 23 per cent; in 1876 to 22½; while in 1877 it takes a turn and rises to 28 per cent. — a larger proportion than before since 1873. But the chief activity in the Northwest has been in Minnesota and Iowa; the former built nearly twice as much road in 1877 as in the four years preceding, and the two states together have a sixth of the total in the country. The other Northwestern states do not make much of a figure; Illinois, which for several years took the lead, and which has a larger mileage than any other state in the Union, has added very little to its excessively large railroad system, In 1872 686 miles were built in that state, which was 9 per cent. of the total of the year; in 1877 its 33 miles of new road are but 1½ per cent. of the total.

If, however, there has been a restriction of work in one state where the supply is excessive, the contrary has been the case in another. Ohio, which has more non-paying railroads than almost any other state, has largely increased its mileage, and constructed 10½ per cent. of the total in the country. There is to be said of Ohio, however, that, in the first place, though the railroads are much too near together for their own good in most of the state, part of it, until very recently, has been quite destitute; and, moreover, Ohio has become a manufacturing state, with developing business in mining, etc., which may not always be properly served by the old system built chiefly for other objects. At least nearly all the new Ohio roads are local lines, without even a pretence of aiming at that "great through traffic" which has begot and ruined so many railroads in the West and elsewhere. The new Ohio lines are chiefly true secondary railroads, intended to fill a place between the highway and the trunk line, to be worked at moderate speed to accommodate local traffic. Out of the 236 miles credited to that state, no less than 157 are of 3 foot gauge, and made light and cheap. The lightness and cheapness are in every way commendable for roads of their class, but in a state so well supplied with standard roads the narrow gauge will be a much greater disadvantage than in

isolated districts like those of Colorado and Utah, where there is a narrow gauge system which it is often important to conform to.

The mileage of narrow gauge road constructed last year in the entire country was very large—705 miles, and nearly one third of the total. As we have frequently said, there is now little room for costly roads, and it is natural and proper that most of the new ones should be adapted to their circumstances and made cheap and light: and as the only cheap and light railroad with which the community of this generation at large is familiar is of narrow gauge, we may expect their construction to continue until examples of equally cheap railroads of standard gauge are frequent enough to be generally known.

Although the last half of the year was more prosperous than the first half, railroad construction does not seem to have been much affected thereby, the proportion constructed in the last half being about as usual. Naturally we would expect an improvement in business to be felt later, and if at all, during 1878. We do not, however, yet hear of any unusual number of new projects which are likely to be undertaken. There are, however, a number of unfinished lines on which work is now in progress. Of the lines on which road was built last year, 44, according to our best information, are still in progress or likely soon to be extended further while several more may have work resumed on them. Most of them, however, will be short lines when they are finished, and we hear of no long line which is sure to be constructed in 1878, though the extension of the Cincinnati Southern road is altogether probable, we suppose. The farther rapid building of the Texas & Pacific will depend, we suppose, on the action of Congress, and also to some extent that of the Southern Pacific. The latter will probably make some extension into Arizona, unless the Texas & Pacific is subsidized all the way to Fort Yuma, but not if it is. The Northern Pacific may do something towards completing its great line, but probably not a great deal. A number of Texas roads are ready to be built long distances, if the money can be got; but no great revival of construction can be looked for this year. A second heavy harvest in the Northwest would probably stimulate immigration, and there is plenty of room on good land for railroads in Western Minnesota and Iowa and Eastern Nebraska, if only people will establish farms there. But again the chief part of the work will probably be for local roads, for which there is abundance of room east and west, if made strictly to suit their circumstances—very light, very cheap, and worked at very low speeds.—*R. R. Gazette.*

### ENGINEERING STRUCTURES.

**W**IRE FOR THE EAST RIVER BRIDGE.—Proposals were recently called for the supply of the steel wire for the suspending ropes of the East River Bridge. The specifications require 325,000 pounds of wire rope, making, 70,000 lineal feet in all. There are two sizes required, one measuring  $1\frac{1}{2}$  inches in diameter

weighing  $4\frac{1}{2}$  pounds to the lineal foot, and having a breaking strength of not less than 180,000 pounds; the other measuring  $1\frac{3}{4}$  inches in diameter weighing 5 pounds to the lineal foot, and having a breaking strength of 200,000 pounds. The attention of the members of the board was called to a gnarled, broken, and twisted suspender rope. This specimen was made at the factory of Roebling's Sons & Co., by the direction of Chief Engineer Roebling. It was  $1\frac{3}{4}$  inches in diameter, and had been tested by the Keystone Bridge Company, of Pittsburg. It was broken under a strain of 197,500 pounds, the required strength being 180,000 pounds. It was resolved to award the contract to J. A. Roebling's Sons & Co. at seven cents a pound, for Bessemer steel wire.

**BRIDGE LAWS IN FRANCE.**—A circular of the Minister of public works, promulgated July 9, 1877, and published in the *Annales des ponts et Chaussées* for October, sets forth the requirements with regard to design and testing, which all iron bridges hereafter erected in France must fulfill. These requirements, says the circular, are the result of a careful consideration of the subject by a commission of Engineers, especially convened to study the previously existing laws, and to advise concerning modifications and alterations. Since the Ashtabula disaster, the necessity of some governmental oversight in the erection and inspection of bridges has been pretty well admitted among engineers; hence we give a brief abstract of the French circular, trusting that it may prove suggestive to all who are engaged in the good work of attempting to make our lawgivers appreciate the importance of such systematic regulations.

The circular first treats of railway bridges; these are to be so proportioned, or rather each member is to be so proportioned that in the most unfavorable position of the load the strain shall never exceed the following limits; for cast iron in direct tension,  $1\frac{1}{2}$  kilograms per square millimeter, in flexural tension 3 kilograms, and in compression 5 kilograms; for wrought iron or rolled iron in either tension or compression 6 kilograms per square millimeter. Designers must be able to show by detailed calculations that all pieces are so proportioned that these strains can never be surpassed; but the administration reserves the right to assign higher limits for very long bridges, or in other special cases. Nothing is said regarding variation of the working compressive strain according to the length of the piece, a point which we properly consider of much importance; Gordon's formula in fact seems scarcely to be known in France and Germany.

The rolling load to be used in computation is required to vary with the length of the span according to a tabulated scheme from which the following are a few values; 12,000 kilograms per linear meter is assigned for spans of two meters in length, 9800 kilograms for spans of 5 meters, 7300 kilograms for 10 meters, 4900 for 20 meters, 4100 for 40 meters, 3700 for 60 meters, 3200 for 100 meters, and 3000 for spans of 150 meters and upwards. These loads are for single track bridges.

Each span is to be subjected to two tests, one by a stationary load and the other by a rolling load. These are to be made by trains equal at least in length to the span to be tested, the locomotive with its tender weighing 72 tons and each car weighing 15 tons. This train is to be brought upon the bridge and kept there standing for two hours after all signs of deflection have ceased. For continuous bridges each span is to be thus loaded independently of the others and afterwards each two spans. No mention is made of measurements of deflections or other observations attending these tests, but being under official control of government engineers such records are undoubtedly kept in full detail.

For the rolling load tests the train just mentioned passes over the bridge at the rate of 25 kilometers per hour, and afterwards another train composed of cars, equal in weight to the most heavily loaded passenger cars, passes first with the velocity of 35 and secondly with a velocity of 50 kilometers per hour. For double track bridges each track is to be tested independently and then both together, the two trains in this case moving in the same direction with the assigned velocities.

The use of a locomotive weighing with its tender more than 72 tons is not allowed, except by a special dispensation from the minister of public works. When the rolling stock which is to use the bridge is considerably lighter than that of the above testing train the administration will decide whether or not a less rolling load than that given in the schedule may be allowed in the computations.

For iron highway bridges the same limiting working strains are assigned. The computation must be made for the most unfavorable position of a uniform rolling load of 300 kilograms per square millimeter, or of vehicles closely covering the bridge and weighing if on two wheels 11 tons each, and if on four wheels 16 tons each, that being chosen which is the greatest. The sidewalks are to be proportioned for 300 kilograms per square meter. The tests are to be made by covering the bridge, sidewalks included, with a load equivalent to that employed in the computation and allowing it to remain two hours after all signs of settling have ceased, and also by the passage of loaded vehicles. The use of vehicles heavier than those employed in the computation is forbidden except by special permission of the préfet.—*Engineering News.*

## ORDNANCE AND NAVAL.

IN all future wrought iron muzzle-loading howitzers of 8 inch calibre, manufactured at the Royal Gun Factories, Royal Arsenal, Woolwich, planes are to be cut upon the surface for the application of the spirit level, quadrant, or clinometer in the following positions:—(1) immediately in front of the vent for use in elevating; (2) on the front of the breech coil; (3) on the cascable bottom. These two are for use in taking the level of the trunnions. These planes will enable the operations of ele-

vating and leveling the trunnions to be carried out with greater readiness and accuracy than hitherto.

MR. ICELY, the inspector of Machinery at Portsmouth, has received instructions from the Admiralty to conduct a series of experiments on board the new steel despatch vessel the *Iris*, for the purpose of determining the best form of screw propeller for the sister ship, the *Mercury*, under construction at Pembroke. The first trial will be made under precisely the same conditions as the trial recently conducted, by Messrs Maudslay, with the object of seeing whether the same power can be developed by the engines after having been opened up. Subsequent trials will be made with the ship going at fifteen, twelve, and even as low as four and two-and-a-half knots an hour, provided the engines can be worked at so exceptionally low rate of progress. At the reduced speeds the whole of the cylinders are to receive their steam direct from the boilers. Previous experiments have proved that with twin-screw ships better and more economical results can be obtained at low speeds by disconnecting one of the engines. At the second series of experiments each of the screws will be deprived of two of their blades, and the ship be propelled by two-bladed fans with various pitches.

THE new quick despatch vessel, *Iris*, 10, which was constructed of steel at Pembroke, and engined by Messrs. Maudslay, Sons, and Field, made a preliminary contractor's trial of her novel four cylinder engines at Portsmouth on Friday in charge of Captain Jones, of the Steam Reserve. Mr. James Wright, engineer-in-chief, and Mr. Bakewell, assistant engineer inspector, represented the Admiralty, and Mr. Walter Maudslay and the Hon. George Duncan the contractor's firm. The trial proved very satisfactory, the machinery working well, the boilers exhibiting no signs of priming. After a long spin to the eastward the ship made four runs on the measured mile in Stokes bay, the results being 16.981 knots, 15.652 knots, 17.308 knots, and 15.789 knots, thus realizing a mean speed of 16.45 knots per hour. This is about a knot below the estimated speed, but the data leave little doubt that at these special trials the surprising speed of 17½ knots will be got out of the ship. The revolutions varied from eighty-five to ninety per minute, the estimated revolutions to develop the contract horse-power (7000) being ninety-five. As it was, the indicated power amounted to 6857 horses. The steam in the boilers was at the full pressure of 60 pounds, but the engines could not take all that was generated. It is probable, therefore, that the pitch of the screw, which is at present 18 feet, may have to be made slightly finer. Notwithstanding the fact that the double bottom of the ship was filled with water and 20 tons of iron ballast were on board, the ship was nearly 2 feet short of her load draught. The *Iris* is steered entirely by hand, and it was found that, with the engines going at full speed, it took twelve men to put the helm over 15 deg.

**STEAM GEAR FOR HEAVY GUNS.**—The steam gear for the 38 ton gun carriage designed by Mr. Butler, of the Royal Carriage Department, and described in *THE ENGINEER* of Dec. 15th, 1876, has been brought through its experimental stages successfully, and has now for some time been working as a service carriage should work, with all going well as a matter of course. On Friday last Dec. 14th, experiments were made at Shoeburyness to test its behavior, when the gun was fired with charges increasing upwards from the service one of 130 pounds employed with the gun in an unchambered state. Thus, charges of 140, 150, 160, 170, and 180 pounds were fired. The strain thrown on the carriage was very severe, but it stood well. It has been a matter of dispute as to what is the exact movement of the carriage under the shock of discharge. Mr. Butler devised a simple expedient for obtaining a diagram which appears to dispose of this question satisfactorily. He fastened a long strip of paper on a vertical board parallel to the side of the carriage, and to the latter he attached a pencil which was kept by means of a spring with its point—which was a round blunt one—in contact with the paper. By this means a line was traced along the paper by the pencil when the carriage was run up, showing what would be its path when the carriage ran smoothly on the platform. On firing the line described by the pencil during the recoil of the carriage exhibited an irregularity of movement somewhat on the plan of the diagram of a steam engine. It was by this means found that on the first shock of recoil the carriage is pressed or driven down to the extent of  $\frac{1}{16}$  inch. It then rises gradually, crossing the normal line, and eventually near the termination of the recoil rising to a height of  $3\frac{1}{4}$  inches. The loading operations are facilitated by running the carriage so far back that a portion of it overhangs the end of the slide, by which arrangement space is allowed to push the shot home by the rammer from off its cradle down the bore of the gun, the intermediate movement being done away with. A new engine is likely to be sent to Shoeburyness, double the power of the present one, with which very rapid loading indeed may be expected.

### BOOK NOTICES

**QUANTITIES : A TEXT BOOK FOR SURVEYORS.** By BANISTER FLETCHER, F. R. I. B. A. London: B. T. Batsford. For sale by D. Van Nostrand. Price \$3.00.

The title of the book suggests its plan. It is a guide to estimates for all kinds of building work.

Beginning with earthwork, it includes brickwork, slating, masonry, carpentry, joinery, gas fitting, plastering, plumbing, painting, glazing and paperhanging.

A chapter is devoted to each of these departments of labor; and the rules for estimating are clearly stated, and illustrative examples given in tabulated form.

The illustrations, forty-two in number, are good.

**A PRACTICAL TREATISE ON LIGHTNING PROTECTION.** By HENRY W. SPANG. Philadelphia: Claxton, Remson & Haffelfinger. For sale by D. Van Nostrand. Price 50 cts.

The author has evidently carefully considered the causes of failure of lightning rods to afford protection in cases where they have equally failed, and has brought to bear on the subject of the improvements necessary, a knowledge derived from several years experience in telegraphy.

He is confident that absolute protection to life and property may be afforded by a proper system.

**POPULAR ASTRONOMY.** By SIMON NEWCOMB, LL. D. New York. 1878. For sale by D. Van Nostrand. Price \$4.00

Of the many popular treatises on Astronomy this is to us the most satisfactory. The distinction between what is known and what is inferred is throughout so carefully preserved that the reader is in no danger of being misled by the enthusiasm of the scientists, into an acceptance of doubtful theories.

The author has presented a condensed view of the history, methods, and results of Astronomical research in such style as to be understood without mathematical study.

The eminence of the author is a guaranty of the precision of the work.

**VOLUMETRIC ANALYSIS.** By Dr. EMIL FLEISCHER. Translated by M. M. PATTISON MUIR, F.R.S.E. London: Macmillan & Co. For sale by D. Van Nostrand. Price \$2.50.

The methods of Volumetric Analysis seem to be growing in favor. Each new treatise seems to be extended to the analysis of substances not previously embraced.

This work, like the previous ones, affords instruction at considerable length upon the methods of volumetric analysis, the preparation of standard solutions, etc.

A portion of this work treats of the separation of the bases preceding volumetric estimations; also of the separation and estimation of the more important acids.

Analysis of commercial substances receives a fair share of attention.

The work is well printed, and presents a few excellent woodcuts.

**THE ECONOMIC THEORY OF THE LOCATION OF RAILWAYS.** By ARTHUR M. WELLINGTON, C.E. New York: The Railroad Gazette. For sale by D. Van Nostrand. Price \$2.00.

Considering the importance of this subject, it is surprising that it has never been so fully treated before. It is clear that no one but a practical engineer could do it, and one, moreover, with a special talent for analysis and classification of facts, that present at the same time physical and financial aspects.

A brief inspection of the book has satisfied us that the work of preparation could not well have been in better hands.

The typography is somewhat trying, but it seems certain that when railway building is again resumed, a great many engineers will endure such discomfort as results from a close study of it.

**RAILWAY DISBURSEMENTS, AND THE ACCOUNTS INTO WHICH THEY ARE NATURALLY DIVIDED.** By MARSHALL M. KIRKMAN. New York. 1878. For sale by D. Van Nostrand. Price \$2.00.

This work is offered as a convenient guide to the proper performance of the duties of accountants of railway business.

The author is evidently a complete master of the art of classification, and has presented in this book a system which embraces all necessary details, brought under a scientific method of arrangement.

Nothing in the way of clearness is wanting to explain the method. There are nearly sixty pages of blank forms.

**ELEMENTS OF GEOLOGY.** By Joseph LE CONTE. New York. 1878. For sale by D. Van Nostrand. Price \$4.00.

If this work, says the author in his preface, have any advantage over others already before the public, it is chiefly in a fuller presentation of some subjects in dynamical and structural geology, and in the attempt to keep evolution in view, and to make it the central idea of the history.

Every student of geology will we think regard this work as an invaluable contribution to science, whether he regards evolution as a "central idea" or not. The prominence given to the geology and physical geography of our own continent will prove especially acceptable to American students.

The arrangement of subjects and the mechanical execution of the work are all that could be desired.

**THE USE OF STEEL FOR CONSTRUCTIVE PURPOSES; METHOD OF WORKING, APPLYING AND TESTING PLATES AND BARS.** By J. BARBA, Chief Naval Constructor at L'Orient. (Translated from the French). With a preface by ALEX. L. HOLLEY, C.E. 80 cuts. New York: D. Van Nostrand. 110 pp. 12mo. Price \$1.50.

This latter work especially concerns American steel works, and its presentation to them by our leading authority on the subject is especially happy and especially well done.

In this country we have at hand all the elements for successful steel using on the largest scale for ship and bridge building; our system of ultra-light construction points rather towards steel than towards iron; and yet our chief and almost exclusive use for American-made Bessemer is for rails; while the Martin makers have not given us metal cheaply enough for larger than spring and boiler-plate service. The nature and uses of steel are not sufficiently understood. Experiments and investigations, such as those of Barba, have been lacking; and hence we have had no impetus towards increasing uses of the greatly superior metal. There can be no doubt about it that the age of iron approaches its close, and that that of the various steels has scarcely dawned, although giving promise of a glorious future. In fact, construction steel and steel construction are practically unknown to us. We do not know how to construct and handle the material, and our failures have taught us much less than we

can learn from the magnificent successes at Terre Noire and L'Orient, and the ingenious and thorough experiments and deductions of Barba.

To the keen analyst, whether or not practically familiar with the difficulties in steel constructions, the work before us reads like a key to the mysteries of materials and forces. How to "humor," manipulate and manage the remarkable series of carburets, which we call steel, is distinctly set forth; the drawings and tables of tests are concise, admirably arranged and carefully used as bases for incontrovertible generalizations. We have had occasion to draw largely from these notes, and shall doubtless do so again; and take pleasure in commending it to the artisan in iron and steel as instructive and practical.—*Railway Review*.

### MISCELLANEOUS.

**MANGANESE BRONZE.**—We have from time to time spoken of the alloy introduced some time since by Mr. P. M. Parsons, under the name of manganese bronze, and which exhibits extremely high tensile strength combined with extraordinary toughness and power of extension. The various grades in which this alloy can be made and the facility with which it adapts itself to forging and other manufacturing processes, makes it peculiarly adapted for a great variety of constructive purposes, where lightness and strength are required. The following Table gives the results of a series of experiments recently made at the Royal Gun Factories, Woolwich, to ascertain the comparative strengths of the manganese bronze, Muntz's metal, and gun metal. The diameter of the specimens was .533 inch, and the length exposed to test 2 inches.

Number.	Material.	Strain per Square Inch.		Ultimate Elongation in 2 inches.
		Elastic Limit.	Breaking Strength.	
	<i>Parsons' Manganese Bronze Bolt Rod.</i>	tons.	tons.	per cent.
1	Cold rolled.....	34.4	39.6	11.6
2	Forged and annealed.	16.6	30.7	20.7
3	Hot rolled & annealed	15.2	27.4	12.8*
4	Cold " "	14.5	29.1	18.3
5	Hot rolled mild quality	11.0	29.0	45.6
	<i>Muntz Metal.</i>			
6	Rolled and annealed.	7.8	24.0	54.6
	<i>Gun-metal.</i>			
7	Cast.....	7.0	16.0	16.6

\* This specimen was not broken through the shank but gave way prematurely at the base of the thread where the head was screwed on, owing to its having been nicked by the turning tool.

The results recorded speak for themselves, and fully justify the confidence placed in the alloy by manufacturers who are now employing it on an extended scale.—*Engineering*.

THE United States War Department has lately republished from the surveys of the Austrian staff a most excellent series of maps of European Turkey, in sections containing each about four degrees of the earth's surface, the sheets measuring  $16\frac{3}{4}$  inches by 19 inches, thus making a very large map, nearly an inch to six miles in scale. Between this series and all other maps of the field of battle in the East that have yet been published in America there is no sort of comparison, and the arrangement of the sections, with an index on the margin showing how to arrange them to make a wall map, gives them the advantages of portability combined with those of the large scale. The only objection, says the *U. S. Army and Navy Journal*, that we can see to the maps for American use is the retention of the German nomenclature, but that is unavoidable under the photo-lithographic process of reproduction, without redrawing the maps, an expense unwarranted by the appropriations for the Engineer Department. We hope soon to see Asia Minor mapped as well.

THE SPHEROIDAL STATE.—Professor Barratt gave on the 3d inst., at the London Institution, a lecture on "New Views of the Spheroidal State." He first reminded the audience what the condition was which is expressed by the words "spheroidal state." When we allow water to fall on a warm surface, such as the hob of a grate, it rapidly evaporates without noise. If the surface be nearly red hot, the water instantly and noisily hisses into steam. Reasoning onwards from these facts, we should conclude that if the surface be intensely hot—at a white heat, for example, the water would flash into vapor, and disappear the moment it touched the iron. But this is not so; and it is often here we are met with one of those anomalies that so often arrest us, and show the need of putting *a priori* conclusions to the test of actual experiment. The anomaly in this case is this: Water, or any other liquid, falling on a red-hot surface, does not flash into steam, but rolls about on the glowing surface in liquid drops comparatively cool. They are not perfectly spherical, owing to gravity, but this is their anomalous deportment which has been termed the spheroidal state of liquids. So far back as 1746 Eller studied the phenomena, and Leidenfrost, a German philosopher, in 1797 published an elaborate dissertation on the subject. He, and after him Klaproth, proved that the drops were below the boiling point of the liquid used, and their explanation of the phenomena is that which has been generally accepted to the present time. Their explanation was this:—By its first contact with the hot surface, part of the liquid is suddenly turned into vapor. This vapor has a definite and considerable tension or pressure. The pressure thus generated acts in opposition to gravity, for it tends to push back the atmosphere above, and with it the liquid drop. It would soon be equalized, and the drop would no longer be

sustained, were it not that the proximity of the hot surface constantly generates more vapor and thus renews the upward pressure. Hence the drop is buoyed up by a shield of its own vapor on which it rests as a mobile elastic spring. The contractile force which exists on the surface of all liquids tends to draw the particles of the liquid into the smallest compass, and by what is known as the superficial tension of the liquid, the drop freed from the adhesion of the solid gathers into a little spherical drop. This has been the state of our knowledge up to the present time. Among the experiments which were used in illustration of this part of the lecture, it was shown very successfully by an enlarged image on the screen that a space really did exist between the drop and the heated metal on which it rested. Many allusions to the fiery ordeal and to more modern handling of heated metals were made, which are explicable in consequence of the knowledge that with a fluid on the skin highly heated metal cannot touch it. M. Boutigny, some twenty years ago, showed that even nitric acid on a copper dish, when thrown by heat into a spheroidal state, would not touch the copper. But there are cases in which the old explanation cannot hold good. For example, in some states of the weather, the water splashed up in rowing will be noticed falling back and rolling in spheroidal drops. So, too, spirits of wine and petroleum may be agitated by vibrations from a bow drawn across a glass that contains them till they throw up globules which roll about on the surface. It is here, Professor Barratt said, that Mr Johnstone Stoney's investigations on the forces which produce the motion in the little vanes in Mr. Crookes's radiometer come into consideration. To Mr. Stoney, he said, is unquestionably due the great honor of having been the first fully to explain the true theory of the radiometer. It was in the course of these investigations that Mr. Stoney had quite recently been led to show that the force which is so active in the high rarefaction (that is necessary for the effective rotation of the radiometer) is also present at ordinary atmospheric tensions. Now it is this force which forms the new explanation of the entire phenomenon of the spheroidal state. Professor Barratt proposed to call it "Stoney's force." In order to understand the action that occurs it must be recollected that, according to calculations, the number of molecules of air that at ordinary pressure occupies the space of a pin's head is 1,000,000,000,000,000,000; when the radiometer globe is exhausted of these molecules of air as far as we can do it by mechanical means, there are still some millions remaining, and these are in constant motion. Heat makes them move more rapidly, cold more slowly. If we have two surfaces very near each other, one surface hot and the other cold, from the hot surface the molecules will be thrown off with greater rapidity than they reached it; and if the cold surface be near enough they will "bombard" it. Hence there will be a tendency in the hot and cold surfaces to retreat from one another, and when with one of these, as in the radiometer, this is possible, it ensues.

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A NEW GENERAL METHOD IN GRAPHICAL STATICS.

By HENRY T. EDDY, C. E., Ph. D., University of Cincinnati.

Written for VAN NOSTRAND'S MAGAZINE.

IV.

ANY FORCES LYING IN ONE PLANE, AND  
APPLIED AT GIVEN POINTS.

We have previously referred to this problem, having treated a particular case of it in Fig. 2; and subsequently certain statements were made respecting the indeterminateness of the process for finding the reactions of supports in case the applied forces were not vertical.

The case most frequently encountered in practice is wind-pressure combined with weight, and we can take this case as being sufficiently general in its nature; so that we are supposed to know the precise points of application of each of the forces, and its direction. Now it may be that the reaction of the supports cannot be exactly determined, but in all cases an extreme supposition can be made which will determine stresses in the framework which are on the safe side.

For example, if it is known that one of the reactions must be vertical, or normal to the bed plate of a set of supporting rollers, this will fix the direction of one reaction and the other may then be found by a process, like that employed in Fig. 2, of which the steps are as follows:

Resolve each of the forces at its point of application into components parallel

and perpendicular to the known direction of the reaction, which we will call vertical for convenience, since the process is the same whatever the direction may be. By means of an equilibrium polygon or frame pencil find the line of action of the resultant of the horizontal components, whose sum is known. Then this horizontal resultant, can be treated precisely as was the single horizontal force in Fig. 2, which will determine the alteration of the vertical components of the reactions due to the couple caused by the horizontal components.

Also, find by an equilibrium polygon, or frame pencil, the vertical reactions due to the vertical components. Correct the point of division  $q$  of the weight line as found from the vertical components by the amount of alteration already found to be due to the horizontal components. Call this point  $q'$ , then the polygon of the applied forces must be closed by two lines representing the reactions, which must meet on a horizontal through  $q'$ ; but one of them has a known direction, hence the other is completely determined.

This determination causes the entire horizontal component to be included in a single one of the reactions, and it is usually one of the suppositions to be

made when it is not known that the reaction of a support is normal to the plane of the bed joint.

Another supposition in these circumstances is that the horizontal component is entirely included in the other reaction; and a third supposition is that the horizontal component is so divided between the reactions that they have the same direction. These suppositions will usually enable us to find the greatest possible stress on any given piece of the frame by taking that stress for each piece which is the greatest of the three.

In every supposition care must be taken to find the alteration of the vertical components due to the horizontal components. This is the point which has been usually overlooked heretofore.

#### KERNEL, MOMENTS OF RESISTANCE AND INERTIA: EQUILIBRIUM POLYGON METHOD.

The accepted theory respecting the flexure of elastic girders assumes that the stress induced in any cross section by a bending moment increases uniformly from the neutral axis to the extreme fiber.

The cross section considered, is supposed to be at right angles to the plane of action or solicitation of the bending moment, and the line of intersection of this plane with that of the cross section is called the axis of solicitation of the cross section.

The radius of gyration of the cross section about any neutral axis is in the direction of the axis of solicitation.

It is well known that these two axes intersect at the center of gravity of the cross section, and have directions which are conjugate to each other in the ellipse which is the locus of the extremities of the radii of gyration.

We shall assume the known relation

$$M = SI \div y$$

in which  $M$  is the magnitude of the bending moment, or moment of resistance of the cross section,  $S$  is the stress on the extreme fiber,  $I$  is the moment of inertia about any neutral axis  $\alpha$ , and  $y$  is the distance of the extreme fiber in the direction of the axis of solicitation, *i. e.* the distance between the neutral axis  $\alpha$  and that tangent to the cross section which is parallel to  $\alpha$  and most remote

from it, the distance being measured along the axis of solicitation.

Let  $M = Sm$  in which  $m$  is called the "specific moment of resistance" of the cross section; it is, in fact, the bending moment which will induce a stress of unity on the extreme fiber.

$$\text{Now} \quad I = k^2 A$$

in which  $k$  is the radius of gyration and  $A$  is the area of the cross section.

$$\text{Let} \quad k^2 \div y = r, \therefore m = rA,$$

is the specific moment of resistance about  $\alpha$ , and when the direction of  $\alpha$  varies,  $r$  varies in magnitude:  $r$  is called the "radius of resistance" of the cross section. The locus of the extremity of  $r$ , taken as a radius vector along the axis of solicitation, is called the "kernel."

The kernel is usually defined to be the locus of the center of action of a stress uniformly increasing from the tangent to the cross section at the extreme fiber. It was first pointed out by Jung,\* and subsequently by Sayno, that the radius vector of the kernel is the radius of resistance of the cross section measured on the axis of solicitation. This will also appear from our construction by a method somewhat different from that heretofore employed.

Jung has also proposed to determine values of  $k$ , by first finding  $r$ ; and has given methods for finding  $r$ . We shall obtain  $r$  by a new method which renders the proposal of Jung in the highest degree useful.

The method heretofore employed by Culmann and other investigators has been to find values of  $k$  first, and then having drawn the ellipse of inertia to construct the kernel as the locus of the antipole of the tangent at the extreme fiber. The method now proposed is the reverse of this, as it constructs several radii of the kernel first, then the corresponding radii of gyration, and from them the ellipse, and finally completes the kernel. In the old process there are inconvenient restrictions in the choice of pole distances which are entirely avoided in the new process.

Let the cross section treated be that

\* "Rappresentazioni grafiche dei momenti resistenti di una sezione piana." G. Jung, Rendiconti dell' Instituto Lombardo, Ser. 2, t. IX, 1876, No. XV. "Complemento alla nota precedente." No. XVI.

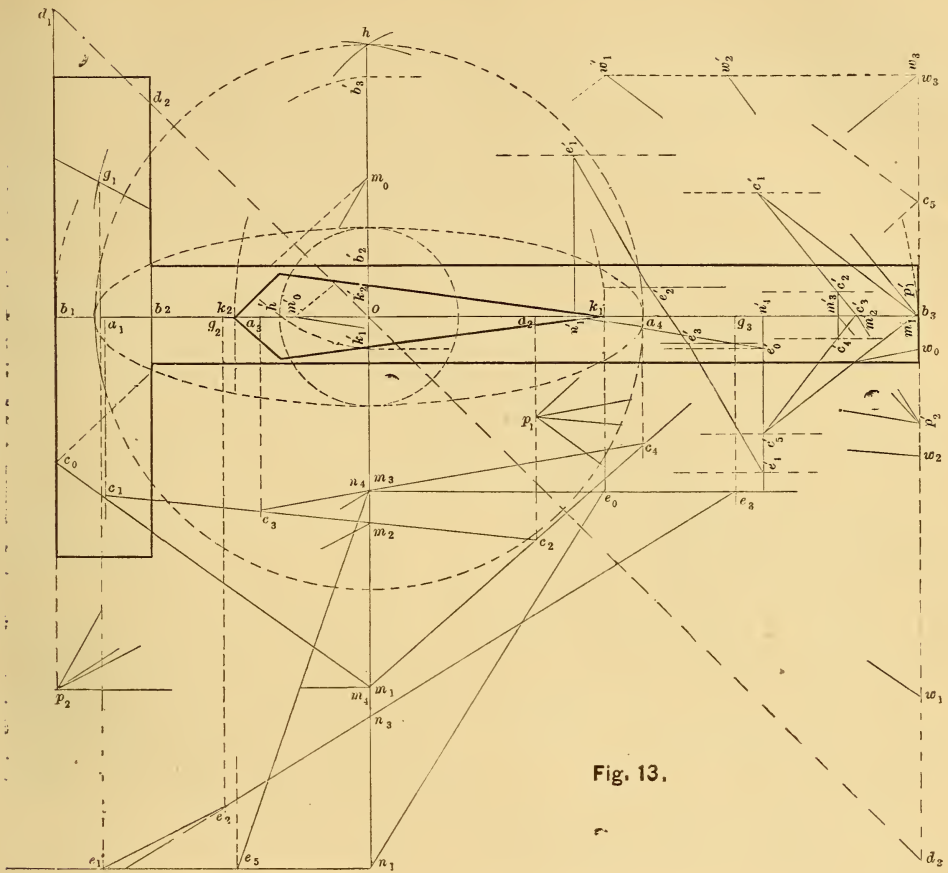


Fig. 13.

of the **T** rail represented in Fig. 13, which is  $4\frac{1}{2} \times 2\frac{1}{2}$  inches and  $\frac{1}{2}$  inch thick. We have selected a rail of uniform thickness in order to avoid in this small figure the numerous lines needed in the summation polygon for determining the area; but any cross section can be treated with ease by using a summation polygon for finding the area.

To find the center of gravity, let the weights  $w_1, w_2$  and  $w_3, w_4$ , which are proportional to the areas between the verticals at  $b_1, b_2$  and  $b_2, b_3$ , be applied at their centers of gravity  $a_1$  and  $a_2$  respectively; then the equilibrium polygon  $c_1, c_2$ , having the pole  $p_1$ , shows that  $o$  is the required center of gravity.

Let the area  $b_2, b_3$  be divided into two parts at  $o$ , then  $w_2, w_3$  and  $w_4, w_5$  are weights proportional to the areas  $b_2, o$  and  $o, b_3$  respectively; and  $c_3, c_4$  is the equilibrium polygon for these weights applied at their centers of gravity  $a_3$  and  $a_4$ .

The intercepts  $mm$  have been previously shown to be proportional to the products of the applied weights by their distances from the center of gravity  $o$ .

We have heretofore spoken of these products as the moments of the weights about their common center of gravity  $o$ . But the weights in this case are areas and the product of an area by a distance is a volume. Let us for convenience call volumes so generated "stress solids." The elementary stress solids obtained by multiplying each elementary area by its distance from the neutral axis will correctly represent the stresses on the different parts of the cross section, and they will be contained between the cross section and a plane intersecting the cross section along the neutral axis and making an angle of  $45^\circ$  with the cross section.

If  $b_1, b_3$  is the ground line,  $b_1, b_3$  and  $d_1, d_3$  are the traces of the planes between

which the stress solid lies on a plane at right angles to the neutral axis.

The distances of the centers of gravity of the stress solids from  $o$  are also the distances of the points of application of the resultant stresses, and the magnitude of the resultant stresses are proportional to the stress solids. The stress solids may be considered to be some kind of homogeneous loading whose weight produces the stress upon the cross section. The moment of inertia  $I$  is the moment of this stress with respect to  $o$ .

Now the intercept  $m_3m_1$  represents the weight of the stress solid whose profile is  $of_3d_3$ . Its point of application is  $g_3$ , if  $og_3 = \frac{2}{3}ob_3$ . Similarly the weight  $m_3m_3$  has its point of application at  $g_2$  if  $og_2 = \frac{2}{3}ob_2$ . And the weight  $m_1m_2$  is applied in the vertical through  $g_1$ ; for the profile of this stress solid is the trapezoid  $b_1b_2d_2d_1$ , and  $g_1$  is its center of gravity found geometrically. In case the area is divided into narrow bands parallel to the neutral axis the points of application coincide sensibly with the centers of gravity of the bands.

Now take any pole  $p_2$  and construct a second equilibrium polygon  $ee$  due to the stress solids applied in the verticals through  $g_1g_2g_3$ .

The last two sides  $e_1n_1$  and  $e_3n_3$  are necessarily parallel and have their intersection at infinity, for the total stress is a couple.

The intercept  $n_1n_3$  is not drawn through the common center of gravity of the stress solids, *i.e.*, it is not an intercept on the line of the resultant stress, but since parallels are everywhere equidistant this intercept is proportional to the moment of the stresses about their center of gravity; in other words  $n_1n_3$  when multiplied successively by the two pole distances would be  $I$ . We shall not need to effect the multiplication.

Prolong  $c_1m_1$  to  $c_0$  on the tangent to the extreme fiber and draw  $c_0m_0 \parallel p_1w_3$ , then  $m_1m_2$  represents the product of the total weight-area  $w_1w_3$  by  $ob_1=y$  the distance of the extreme fiber, or  $m_1m_0$  is proportional to the volume of a stress solid whose base is the entire cross section and whose altitude is  $b_1d_1=ob_1$ .

Suppose this stress to be of the same sign as that at the right of  $o$ , let us combine it with the stress already treated. Its point of application is necessarily at

$o$ , and its amount is  $m_1m_0$  if measured on the same scale as the other stresses. Draw  $n_1e_0 \parallel p_2m_0$ , then is  $k_1$  on the vertical through  $e_0$  the point of application of the combined stresses. But the combined stresses amount to a stress whose profile is included between  $d_1d_3$  and a horizontal line through  $d_1$ , *i.e.* to a stress uniformly increasing from  $b_1$  to  $b_3$ ; hence  $k_1$  is a point of the kernel as usually defined.

If  $c_1m_1$  be prolonged to  $c_0$  and we draw  $c_0m_0 \parallel p_1w_3$ , then  $m_1m_0$  (not shown) is the weight of a stress solid of a uniform depth  $b_3d_3$  over the entire cross section; and if we draw  $n_1e_0 \parallel p_2m_0$ , then will  $k_2$  on the vertical through  $e_0$  be also in like manner a point of the kernel, *i.e.* the point of application of a stress uniformly increasing from  $b_3$  to  $b_1$ .

But now let us examine our construction further in order to gain a more exact understanding of what the distances  $r_1=ok_1$  and  $r_2=ok_2$  are.

We have shown that  $m_1m_0$  represents the product of the area of the cross section by the distance  $ob_1$  of the extreme fiber, *i.e.* the quantity  $Ay_1$ ; but  $n_1n_3$  represents the moment of this weight when applied at  $k_1$ , *i.e.* the product  $Ay_1r_1$ . Also as previously shown  $n_1n_3$  represented  $I$  on the same scale, hence

$$I = Ay_1r_1, \text{ but } I = Ak_1^2 \therefore r_1 = k_1^2 \div y_1$$

and  $r_1$  is the radius of resistance previously mentioned.

In order to determine the radius of gyration  $k_1$ , which is a mean proportional between  $r_1$  and  $y_1$ , describe a circle on  $b_1k_1$  as a diameter intersecting  $mm$  at  $h$  then  $oh=k$ , the semi-axis of the ellipse of inertia conjugate to  $mm$  as a neutral axis. The accuracy of the construction is tested by using  $b_3k_2$  as a diameter and finding the mean proportional between  $ok_2$  and  $ob_3$ . It should give the same result as that just obtained. In our Fig. both circles intersect at  $h$ .

It is known from the symmetry of figure of the cross section that  $k_1$  is one of the principal axes.

In similar manner we construct the radius of resistance, etc., when  $b_1b_3$  is taken as the neutral axis.

Knowing before hand that this line passes through the centre of gravity, we have taken the weights of the area above it in two parts, *viz.*: that extend-

ing from  $b_1b_2$ , and that from  $b_2b_3$ , and we have taken  $w_1'w_2'$  and  $w_2'w_3'$  respectively, as the weights of these. Choose any pole  $p_1'$  and draw the equilibrium polygon  $c'e'$ : use its intercepts  $m'm'$ , which represent the weights of stress solids, as weights and with any pole  $p_2'$  construct the second equilibrium polygon  $e'e'$  on the verticals through the points of application of the stresses. Also find  $m_1'm_0'$  the product of the total area by the distance of the extreme fiber and make  $n_1'e_0' \parallel p_2'm_0'$ ; then is  $k_1'$  which is on the same vertical as  $e_0'$  a point of the kernel, and  $ok_1' = r_1'$  the radius of resistance. Use  $k_1'b_3'$  as a diameter, then is  $ok_1' = k_1'$  the radius of gyration, for  $k_1'^2 = r_1'y_1'$ . With these two principal axes thus determined, it is possible at once to construct the ellipse of inertia. In any case it will be possible to determine the direction of the axis of solicitation corresponding to any assumed neutral axis by actual construction, it being simply necessary to find the line through  $o$  upon which lie the points of application of the positive and negative stresses considered separately. These axes being conjugate directions in the ellipse of inertia, when we have found the radii of resistance in those two directions we can at once obtain the corresponding radii of gyration which are conjugate semi-diameters, and so draw the ellipse.

After the ellipse is drawn the kernel can be readily completed by making  $r$  in every direction a third proportional to the distance of the extreme fiber and the radius of gyration.

We are assisted in drawing the kernel by noticing that to each straight side of the cross section there corresponds a single point in the kernel, and to each non-re-entrant angular point a side of the kernel, these standing in the mutual relation of polar and anti-pole with respect to the ellipse of inertia, as shown by the equation  $k^2 = ry$ .

In Fig. 13 the point  $k_1$  corresponds to the left hand vertical side, the point  $k_2$  to the right hand vertical side, and the sides  $k_1k_1'$ ,  $k_2k_2'$  to the angular points at the upper and lower extremities of the left side respectively, while the points  $k_1'k_2'$  at the very obtuse angular points of the kernel correspond to the upper and lower horizontal sides of the flange.

The two remaining angular points of the kernel correspond to tangent lines when they just touch the corners of the flange and web, while the intermediate sides correspond to the angles at the extremities of these lines.

#### KERNEL, MOMENTS OF RESISTANCE AND INERTIA: FRAME PENCIL METHOD.

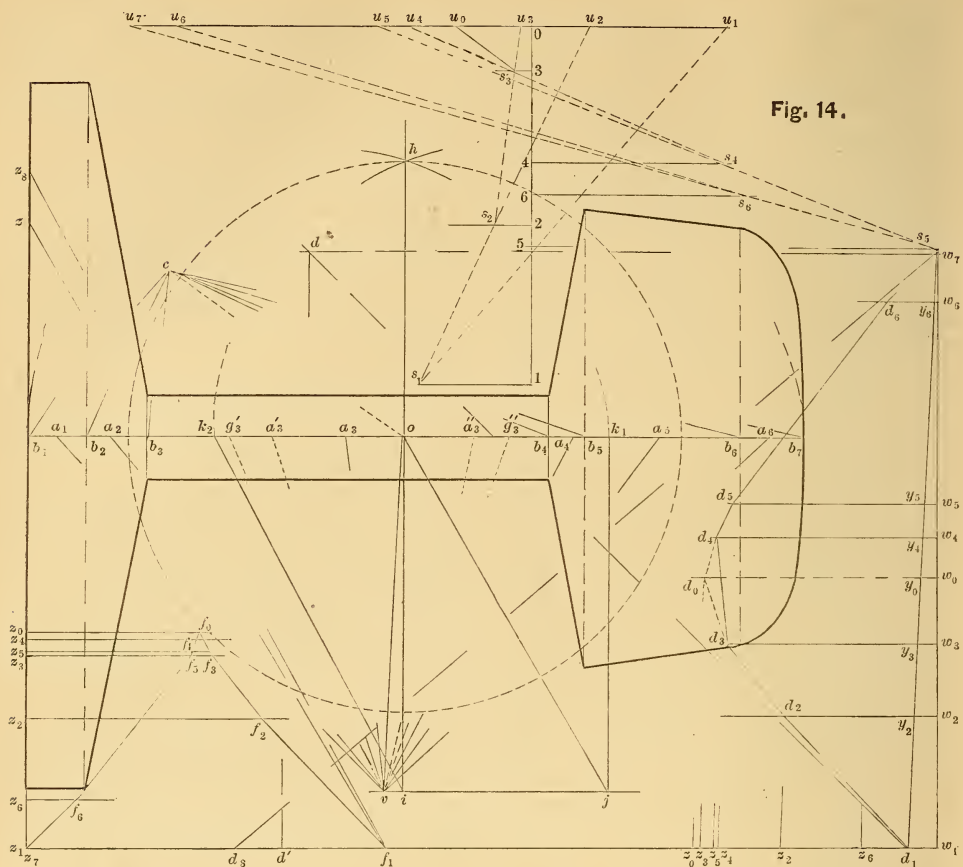
Let the cross section treated be that shown in Fig. 14, which is nearly that of a 56 lb. steel rail, the difference consisting only in a slight rounding at the angles.

Let the cross section be divided by lines perpendicular to the axis of symmetry  $bb$  at  $b_2$ ,  $b_3$ , etc., then the partial areas and the total area may be found by a summation polygon.

Take  $c$  as the common point of the rays through  $b_1b_2$ , etc., and make 01, 02, etc., proportional to the mean ordinates of the areas standing on the bases  $b_1b_2$ ,  $b_2b_3$ , etc. respectively. Draw  $s_1u_1 \parallel cb_1$ ,  $s_2u_2 \parallel cb_2$ , etc., then will the segments of the line  $uu$  represent the respective partial areas, and  $u_1u_1$  will represent the total area.

Divide the vertical line  $wv$  into segments equal to those of the line  $nn$ , then is  $wv$  the weight line for finding the center of gravity etc. of the cross section. Let  $a_1$ ,  $a_2$ ,  $a_3$ , etc., be the centers of gravity of the partial areas, and let  $v$  be the vertex of a frame pencil whose rays pass through these centers of gravity. Draw the equilibrating polygon  $dd$  with its sides parallel to the rays of this frame pencil, then the ray  $vo$  parallel to the closing side  $yy$  of the equilibrating polygon determines the center of gravity  $o$  of the cross section, according to principles previously explained.

It will be convenient to divide the cross section into two parts by the vertical line  $oi$ , which we shall take as the neutral axis. The partial areas  $b_1o$  and  $ob_4$  have  $a_3'$  and  $a_3''$  as their centers of gravity. Make  $s_3u_3 \parallel co$ , then  $w_3$  which corresponds to  $u_3$ , divides the weight line into two parts, representing the areas each side of the neutral axis, and the polygon  $dd$  can be completed by drawing  $d_3d_3 \parallel va_3'$  and  $d_4d_4 \parallel va_3''$ . It has been previously shown that the abscissas  $yd$  represent the sum of the products of the weights (i.e. areas) by



their distances from  $o$ ; and any single product is the difference of two successive abscissas. Project the lengths  $yd$  upon the horizontal  $zz$  by lines parallel to  $yy$ , then the segments of  $zz$  represent the products just mentioned. But these products are the stress solids or resultant stresses before mentioned. Hence  $zz$  is to be used as a weight line and is transferred to a vertical position at the left of the Fig. The points of application of the resultant stresses may without sensible error be taken at the centers of gravity  $a_1, a_2$ , etc., of the partial areas except in case of the segments of the web on each side of  $o$ . For these, let  $og_3' = \frac{2}{3}ob_3$ , and  $og_3'' = \frac{2}{3}ob_3$ , then  $g_3'$  and  $g_3''$  are the required points of application.

Now with the weight line  $zz$ , which consists partly of negative loads, and with the same vertex  $v$  construct the second equilibrating polygon  $ff$ , then  $z_1f_1$  represents the moment of inertia of

the cross section, it being proportional the moment of the resultant stresses about  $o$ . It is seen that the sides  $f_3f_0$  and  $f_0f_4$  are so short that any small deviation in their directions would not greatly affect the result, and that there would therefore have been little error if the resultant stresses in the web had been applied at  $a_3'$  and  $a_3''$ .

Again, draw  $dd_1 \parallel vb_1$ , then the horizontal line  $dw_1 (=d_1d')$  represents  $ay_1$ , the product of the total weight  $w_1w_7$  (*i. e.* the total area of the cross section), by the distance of the extreme fiber  $ob_1 = y_1$ . Use this as a stress solid or resultant stress applied at  $o$  and having a weight  $zz_1 = d_1d'$ , and draw  $oj \parallel zf_1$ ,  $j$  being at the same vertical distance from  $bb$  as  $v$  is; then is  $k_1$ , which on the same vertical at  $j$ , a point of the kernel. For  $k_1$  is such a point that the product of  $ok_1 (=r_1)$  by the weight  $zz_1 (=Ay_1)$  is  $z_1f_1 = I$

on the same scale as  $I$  was previously measured.

Similarly draw  $w_1 d_3 \parallel vb_1$  and make  $z_3 z_1 = d_1 d_3$ ; also draw  $ik_2 \parallel f_1 z_3$ ; then is  $k_2$  another point of the kernel as appears from reasons like those just given in case of  $k_1$ .

Use  $b_1 k_1$  as a diameter, then  $oh$  is a semi-axis of the ellipse of inertia. The same point  $h$  should be found by using  $k_2 b_1$  as a diameter. Another semi-axis of the ellipse of inertia with reference to  $bb$  as a neutral axis, and conjugate to  $oh$  can be determined, using the same partial areas, by finding the centers of gravity and points of application of the

stresses of the partial areas on one side of  $bb$ , the process being similar to that employed in Fig. 13, except in the employment of the frame pencil instead of the equilibrium polygon.

It is to be noticed that the closing side  $f_1 z_1$  of the second equilibrating polygon  $f_1 f_2$  is parallel to a resultant ray which intersects  $bb$  at infinity, the point of application of the resultant of the applied stresses, *i. e.* the stresses form a couple.

When the ellipse of inertia has been found by determining the magnitude and direction of two conjugate axes, the kernel can be readily completed as has been shown in connection with Fig. 13.

### SUPPLEMENTARY NOTE TO THE "NEW CONSTRUCTIONS IN GRAPHICAL STATICS."\*

Attention should be directed to the two senses in which  $M$  is used in our fundamental formulae.

In equation (3) the primary signification of  $M$  is this: it is the numerical amount of the bending moment at the point  $O$ ; and if this magnitude be laid off as an ordinate,  $y_m$  is the fraction or multiple of it found by equation (3).

Now  $M$  assumes, in the equations (3), (4), (5) and (3'), (4'), (5'), a slightly different and secondary signification; *viz.*, the intensity of the bending moment at  $O$ . The intensity of the bending moment is the amount distributed along a unit in length of a girder, and may be exactly obtained as follows:

$$M = \int_x^{x+1} M dx, \therefore \Sigma_o^x (M) = \int_o^x M dx.$$

In this secondary sense  $M$  is geometrically represented by an area one unit wide, and having for its height the average value which ordinate  $M$ , as first found, has along the unit considered.

Thus the  $M$  used in the equations of curvature, bending and deflection is one dimension higher than that used in the equation expressing the moment of the applied forces; but the double sense need cause no confusion, and is well suited to express in the shortest manner the quantities dealt with in our investigation.

Furthermore, in case of an inclined girder such as is treated in Prop. V, if the bending moment  $M$ , which causes the deflection there treated, be represented, it must appear as an area between two normals to the girder which are at the distance of one unit apart.

In order to apply Prop. V to inclined and curved girders, such as constitute the arch with entire exactness, one more proposition is needed.

Prop. If weights be sustained by an inclined girder, and the amount of the deflection of this girder, which is caused by the weights, be compared with the deflection of an hori-

zontal girder of the same cross section, and of the same horizontal span, and deflected by the same weights applied in the same verticals; the vertical component of the deflection of the inclined girder, at any point  $O$ , is equal to the corresponding vertical deflection of the horizontal girder, multiplied by the secant of the inclination.

For the bending moment of both the inclined girder and the horizontal girder is the same in the same vertical, but the distance along the inclined girder exceeds that along the horizontal girder in the ratio of the secant of the inclination to unity; hence the respective moment areas have this same ratio; therefore the deflections at right angles to the respective girders of their corresponding points are in the ratio of the square of the secant to unity; and the vertical components of the deflections are therefore in the ratio of the secant of the inclination to unity.

In applying this proposition to the graphical construction for the arch, it will be necessary to increase the ordinate of the moment polygon at each point by multiplying by the secant of the inclination of the arch at that point. This is easily effected when the ordinates are vertical by drawing normals at each point of the arch; then the distance along the normal whose vertical component is the bending moment is the value of  $M$  to be used in determining the deflection.

In the arches which we have treated the rise is so small a fraction of the span that the secant of the inclination at any point does not greatly exceed unity; or, to state it otherwise, the length of the arch differs by a comparatively small quantity from the actual span. It is a close approximation under such circumstances to use the moments themselves in determining the deflections; and we have so used them in our constructions. A more accurate result can be obtained by multiplying each ordinate by the secant of the inclination of the arch at that point to the horizon.

\* See Van Nostrand's Engineering Magazine, Vol. XVI.

## LIGHTHOUSE MEMORANDA.

By CAPTAIN W. A. JONES, U. S. E., Engineer, Sixth Lighthouse District.

Written for VAN NOSTRAND'S MAGAZINE.

## I.

## RANGE LIGHTS.

A range of lights affords a guide for leading vessels through channel-ways that has the merit of simplicity and precision. It is customary to place two lights on the line of prolongation of the channel, to be marked with the horizontal distance between them, so adjusted to the distance to any point of the channel as to make an ordinary departure from the line at once apparent by the separation of the verticals through the lights. Their angular distance from each other in a vertical plane, measured from the extreme outward point where a vessel would commence using the range, is fixed so as to prevent them from apparently coalescing under the influence of the phenomenon of irradiation.

The rear light of a range should never be obscured, because there are so many chances of its becoming accidentally obscured or extinguished, an event which might lead to disaster. For a similar reason, it would be preferable not to allow the two lights to coalesce at any point of the range.

The apparent size of luminous objects at night is greater than the actual, in consequence of what is termed irradiation. This phenomenon probably proceeds (1) from atmospheric reflection from the field adjacent to the line of sight, and (2) from the effect of the violent contrast between the light and

its dark background. This produces such a vivid image upon the retina of the eye that the molecular excitement of the nerves probably extends beyond the normal outlines of the image. It is variable in amount, increasing with certain conditions of the atmosphere and of the eye, and decreasing with the distance. It can be reduced by the use of glasses, in proportion to their power.

Unless the outlines of a luminous body subtend a visual angle, large enough to render a surface bounded by it visible by day, its outline cannot be visible at night. The luminous object as seen will be made up mostly of irradiation rays. The visual angle of the sun's diameter is large enough to enable its outlines to be seen. The same is true of the moon. With the planets, it is too small for the naked eye, but large enough for a telescope. In the case of the fixed stars, it is too small for even the most powerful glasses.

The visual angle between two range lights—the rear showing above the front—estimated from points along the range line, is a variable function. It increases in value from a minimum  $=0$  at a distance  $=\infty$  from the rear light up to a maximum at a point not far from the front light, from whence it rapidly diminishes to 0 at the point where the angle line is intersected by a line through the two lights.

This subject is susceptible of analytical discussion as follows:

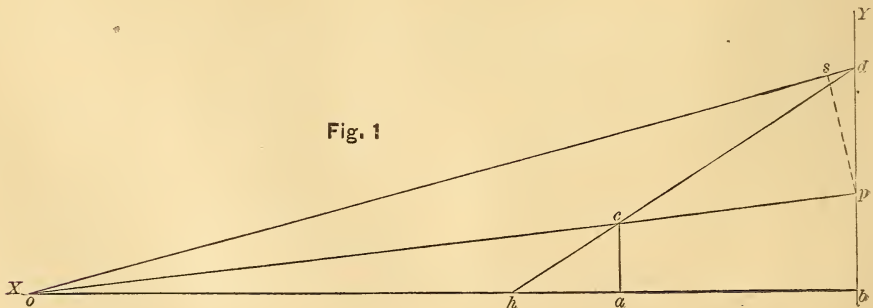


Fig. 1

Let  $bX$  be the axis of  $X$  positive towards  $X$ .

Let  $bY$  be the axis of  $Y$  positive towards  $Y$ .

Let  $ac$  be the front beacon.

Let  $bd$  be the rear beacon.

Let  $bo$  be the horizon line through  $b$ .

Let  $o$  be any position, upon the range of observer's eye.

Let  $V = dop$  represent the visual angle between the lights.

Let  $bo = x$  and  $bp = y$ .

Draw  $ps$  the opening of the visual angle  $v$  at  $p$ .

Let  $p$  represent the angle difference between  $ops$  and  $90^\circ$  at  $p$ .

Then for all values of  $v$  less than 20 minutes, we will have angle  $p$  less than 10 minutes and  $\cos. p = 1$ , also,  $\tan.$

$$V \times op = ps, \text{ or, } \tan. V = \frac{ps}{po}.$$

Now  $ps = rpd$ ,  $r$  being deducible after the assumption of  $x$ .

Represent  $pb + bs = pb + rpd$ , by  $a$  and place  $gx$  for  $po$ ,  $q$  being deducible after the assumption of  $x$ .

We then have  $ps = a - y$  and

$$\tan. V = \frac{a - y}{qx} \quad \dots (1)$$

From triangles  $pob$  and  $coa$  we have after placing  $c$  for  $ac$

$$x : y :: x - ab : c$$

Placing  $l$  for  $ab$ , we have

$$y = \frac{cx}{x - l} \quad \dots (2)$$

Substituting in equation (1) we have

$$\tan. V = \frac{(a - c)x - al}{q(x^2 - lx)} \quad \dots (3)$$

From this equation the value of  $v$  at any point can be obtained by assuming the proper value for  $x$ .

It is evident that  $v$  is not a uniformly varying function. To ascertain the location of its maximum and minimum values, resume equation (3) and place  $m$  for  $a - c$ . Then differentiate this value at  $\tan. v$  and make the first differential coefficient equal to 0. This gives

$$\frac{2alx - mx^2 - al^2}{q(x^2 - lx)(x^2 - lx)} = 0 \quad \dots (4)$$

This equation is of the general form

$$f(ax^4 + bx^3 + cx^2 + dx + e) = 0$$

which has four real roots corresponding to four maximum and minimum states of the function  $\tan. V$ .

Factoring (4) we obtain

$$\frac{1}{q(x^2 - lx)(x^2 - lx)} = 0 \quad \dots (5)$$

and

$$mx^2 - 2alx = -al^2 \quad \dots (6)$$

From (5),  $x = \pm \infty$ . These two values correspond to minimum states of the function  $\tan. v$ . They give in (3)  $\tan. v = 0$  or  $v = 0$ . That is to say, the visual angle is equal to 0 at the distances of  $\pm \infty$  from the rear light at  $b$ .

From (6) we have

$$x^2 - \frac{2al}{m}x = -\frac{al^2}{m}$$

The roots of which are

$$x = +\frac{al}{m} \pm \sqrt{-\frac{al^2}{m} + \left(\frac{al}{m}\right)^2}$$

Two of these are real and positive, and two are imaginary depending upon the value of  $l$ , the two real roots correspond to maximum states of the visual angle  $v$  whose value may be found by substituting in (3). Resuming the values

$$x = +\frac{al}{m} \pm \sqrt{-\frac{al^2}{m} + \left(\frac{al}{m}\right)^2}$$

and replacing for  $m$  the term for which it was substituted we have

$$x = +l \left\{ \frac{a}{a - c} \pm \sqrt{-\frac{a}{a - c} + \left(\frac{a}{a - c}\right)^2} \right\}$$

The first of these values of  $x$  is greater than  $l$  and the corresponding maximum value of  $v$  falls on the range beyond the front light.

The second value is less than  $l$  and greater than 0 for all values of  $c < a$ , and the corresponding value of  $v$  falls between the two lights.

There remains to be considered a minimum value  $v = 0$ , of the visual angle that is not accounted for by equation (4). It occurs at the point  $h$ , where the line through the two lights intersects the range line  $bo$ . Under this condition, however,

$$bp = bd, \text{ or } y = a.$$

Which in (1) gives

$$\tan. v = 0.$$

a minimum state of the function.

Now equation (4) is derived from (1) by substituting therein a value for  $y$ , hence the present condition is such that (4) can have no existence, and therefore it should not account for this particular state of the function.

In the foregoing discussion, the curvature of the earth is not taken into account, since the results will be found sufficiently accurate for practical purposes, and the general conclusions are not affected by it.

Owing to the apparent increase in size of a light affected by irradiation, two lights of a range will coalesce unless they be displayed under quite an appreciable visual angle. Upon the establishment of this angle at a minimum consistent with the separate distinction of each depends, very largely, the economical construction of rear beacons, especially for ranges that extend to long distances from the lights. Indeed, beyond even a moderate distance, the conditions require the construction of a rear beacon of extraordinary height. On flat coasts the difficulty can be overcome and ranges of extreme length established by using for the rear beacon twin towers disposed symmetrically on either side of the range line, so as to show a *horizontal* visual angle between the front light and each of the rear lights on the starboard and port hand. The rear structures can then be made at minimum height. This is an important consideration when we consider that the cost of constructing towers increases very rapidly with increments of altitude.

The three lights can be of the same color, as no practical difficulty will be experienced in distinguishing the one in front from those in rear.

The minimum visual angle can only be determined by a careful series of experiments, so as to introduce all possible elements of its variation. In the French Lighthouse service numerous experiments have been made, and the result, as announced by Reynaud, is that angles of 15 minutes for the 1st, 2d, and 3d orders, and 8 minutes for those of lower orders can be relied upon. In the practice of the U. S. Lighthouse Board, angles of 3 and  $3\frac{1}{2}$  minutes have been found sufficient for range lights. Some

observations recently made by me upon the two first order lights at Nevesink Highlands, New York Harbor, point to a possible reduction below these figures, and also indicate that the effect of irradiation decreases with the distance. This latter would seem almost obvious, since the rays reflected from the field adjacent to the line of sight should be rapidly dispersed with increments of distance, and as the power of a light decreases under the same condition, its contrast effect upon the retina of the eye should be correspondingly reduced.

The minimum visual angle should be established for the extreme outside point, where the range may be used.

Where the channel is sufficiently wide, the rear light is sometimes allowed to coalesce with the front along the extreme outer portion of the range, but the range line must be so disposed as to permit the requisite angle for separate distinction to be opened on either hand before the border shoal is reached. The following discussion will illustrate:

The figure is on a plane through the vertical line of the front light and perpendicular to the vertical plane of the range line.

Let  $a$  be the position of the front light.

Let  $b$  be the position of the rear light projected upon this plane, by a line through the point on the range where the visual angle is a minimum for separate distinction.

Let  $b_1 \dots b_2 \dots b_3 \dots$  be assumed positions of  $b$  under a smaller angle.

Let  $b\beta \dots b_1\beta_1 \dots b_2\beta_2 \dots$  be approximate positions of the lines, over which the rear light will apparently move as observer's eye passes to same side of range line.

Let  $\beta_1 \dots \beta_2 \dots \beta_3 \dots$  be points on these lines where it will give a visual angle sufficient for separate distinction.

Let  $v \dots v_1 \dots v_2 \dots$  represent the visual angle when the rear light is at  $b \dots b_1 \dots b_2 \dots$  respectively.

Let  $d$  represent the distance from the front beacon to the assumed position of observer's eye on the range line.

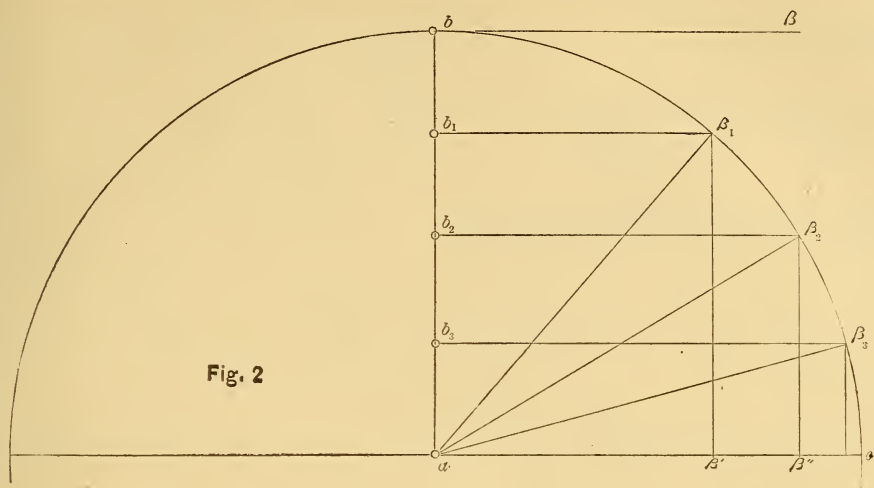


Fig. 2

Now, at this distance we have within the limits of practice

$$ab = \tan. V.$$

Whichever of the above positions be assumed for the rear light the distances  $ab_1, \dots ab_2, \dots$  will be equal to the sines of angles of which  $b_1\beta_1, \dots b_2\beta_2, \dots$  are the cosines, and therefore the

latter can be obtained from the known relation between sine and cosine by assuming values for  $ab_1, \dots ab_2, \dots$ . Thus: if  $ab_2 = \frac{1}{2}ab$  the value of  $b_2\beta_2$  will be 0.866  $ab$ . Knowing  $b_1\beta_1, \dots$  etc., the width of the belt at any point of the range outside of which the two lights will appear separately distinct can be obtained as follows:

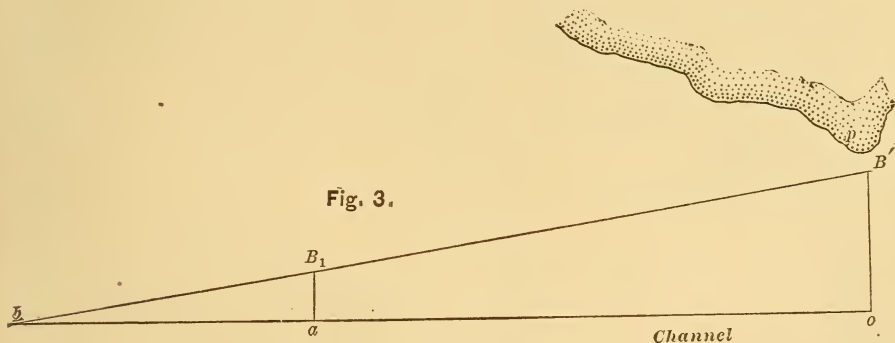


Fig. 3.

In this figure, which is a plan of the range  $bo$ ,  $a$  is the position of the front light,  $b$  that of the rear light,  $o$  the position of the observer's eye on the range

light, and  $p$  the point of the shoal on the starboard hand going towards the lights.

Take the triangle  $bo\beta'$  in the plane through the front light and the line  $o\beta'$

which is perpendicular to  $bo$ . In this triangle we have

$$ba : bo :: a\beta_1 : o\beta'$$

$$\text{But } a\beta_1 = b_1\beta_1 \text{ (Fig. 2)}$$

$$\text{Therefore } o\beta' = \frac{bo \times \beta_1 b_1}{ba}$$

The following example of one of the

two ranges proposed for Port Royal Harbor, South Carolina, will illustrate the general subject:

POQ ... Curve of the earth's surface.

OC' ... Front Beacon.

BC ... Height on rear Beacon intercepted by ray of light  $aC'$  from observer's eye at  $a$ .

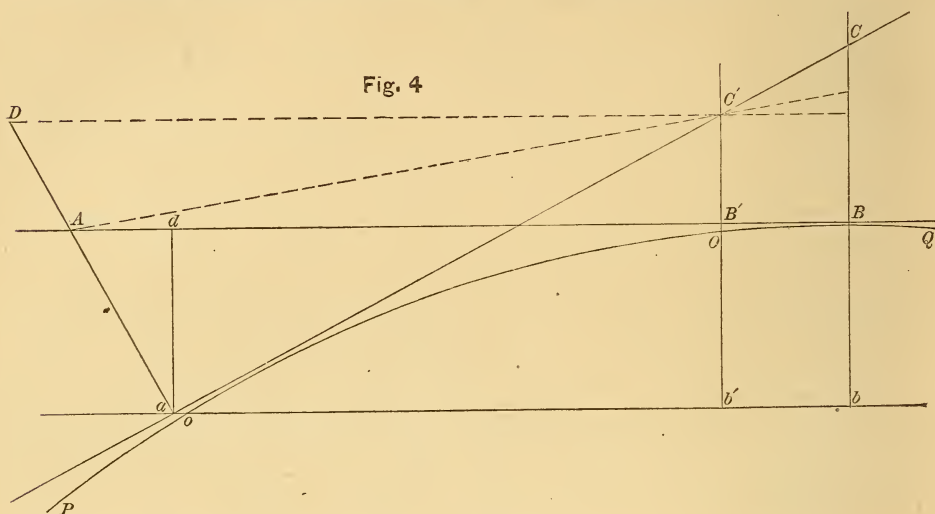


Fig. 4

Do is the vertical at  $a$ ,  $AB$  is the horizon line through  $B$ ,  $ab'b$  is parallel to  $AB$ ,  $ad$  is perpendicular to  $AB$ ,  $BC$  and  $OC'$  are prolonged to  $b$  and  $b'$  on  $ab$ .

$oa = 15$  feet = height of observer's eye above the sea.

$DC'a = Aad =$  Dip of the horizon.

$Ao =$  Curvature correction.

$ad = Aa \cos. Aad.$

$\cos. Aad = 1,000$  for all angles less than  $10^m$ .

Therefore,  $ad = Aa$  for all angles less than  $10^m$ .

PARIS ISLAND RANGE (Fig. 4)

$Bo = 13\frac{3}{4}$  miles,  $B'o = 12\frac{1}{4}$  miles,  $OC' = 45'$ . The value of  $OC'$  is found from the table of corrections for curvature and refraction.  $B'C' = 45' - 1.5' = 43.5'$ .  $Ao =$  difference of level  $= 107'$ .  $DC'a = 6^m 36^s$ , therefore  $ad = Aa$ .  $ad = B'b' = Bb = 107' - 15' = 92'$ .  $b'C' = B'C' + B'b' = 43.5' + 92' = 135.5'$ ,  $ab = Bo \times q$ .  $ab' = B'o \times q$ . From triangles  $abC$  and  $ab'C'$  we have

$$bC = \frac{ab \times b'C'}{ab'} = \frac{Bo \times q \times b'C'}{B'o \times q} = 152.1$$

$$BC = bC - Bb = 152.1 - 92' = 60.1.$$

A visual angle of 3 minutes has an opening of  $63'$  at a distance of  $13\frac{3}{4}$  miles, therefore we have

Height of rear beacon  $= 60.1 + 63' = 123.1$  above the sea level.

## II.

### NUMERICAL DISTINCTION OF LIGHTS AND TOWERS.

It is quite desirable that some means of distinction should characterize any system of lights so that as soon as, or shortly after, a vessel comes in sight of any one, either by day or night, its locality will be clearly announced. Such a system naturally separates itself into two parts, viz., day-marks (1) and lights (2).

#### DAY MARKS.

The most effective means of marking a tower so that it may be distinguished and characterized by day, is by showing upon its surface a certain marked color or contrast of colors. Experience shows and the laws of optics also teach us, that for long distances, the only satisfactory colors for this purpose are black and

white. There is a varying limit beyond which the light from colored objects ceases to be reflected, and the objects will thereafter appear black. White rays are generally thrown as far as the outlines of a tower will show, but not if they are reflected from a surface in strong shadow.

Within the limits of its range, red is a very strongly marked color.

Experience further shows that color contrasts on towers are most readily observed when shown in alternating horizontal bands. The minimum width of a band will be the diameter of the tower where it is placed. A black band of width equal to the diameter of the tower will appear as soon as the outlines of the tower become visible, provided, the distance be not so great or the conditions such that the white rays from the adjacent contrast bands have not been dispersed by the atmosphere.

With the foregoing considerations in view, I have arranged the following system for coloring towers as day-marks:

#### SYSTEM FOR COLORING TOWERS.

(Represent white by 1 and black by 2.)

(1)	2	bands at top of minimum width....	1-2
(2)	2	" " "	2-1
(3)	3	" " "	2-1-2
(4)	3	" " "	2-1-1
(5)	3	" " "	2-2-1
(6)	3	" " "	1-2-1
(7)	3	" " "	1-2-2
(8)	3	" " "	1-1-2
(9)	4	" " "	1-2-1-2
(10)	4	" " "	1-1-2-2
(11)	4	" " "	1-2-2-1

etc., etc.

( $n-1$ )....all black.

( $n$ ).....all white.

No occasion need be found for using more than four bands.

The lantern and gallery should always be black when the background is sky.

The bands are all at the top of the tower and are enumerated from the top downwards. Below the bottom band, the tower should be colored in contrast with it, thus: black, if the band be white, and white, if the band be black.

Selection from the above list will have to be guided and varied by the background upon which the tower is projected. It affords ample variation for the

most extended coasts, since repetition is perfectly allowable beyond reasonable distances.

For short range harbor lights, ample distinction can be secured by coloring the towers all red, or white, or black.

#### LIGHTS.

The most satisfactory light is a fixed white varied by flashes. The flashes should be white, but may be red where the range is not great. A flash can be seen much farther and is picked up with more readiness than a fixed light, but it is difficult to keep the eye fixed upon it when there is much interval or any considerable motion of the vessel. This difficulty is obviated by associating a fixed light with it. A combination is thus afforded that can be observed with ease and precision. Simple flashing lights that flash at intervals exceeding 1.5 minutes are somewhat objectional as it is rather difficult to keep the eye fixed upon them at long range in rough weather.

It should be observed, that at long range a red light can be distinguished by its color only with extreme difficulty and often not at all.

These considerations lead to the following system for the numerical distinction of lights.

#### SYSTEM OF LIGHTS.

(1)	Fixed varied by single flashes.....	1, 1, 1
(2)	" double " .....	2, 2, 2
(3)	" single and double flashed..	1-2, 1-2
(4)	" " " "	2-1, 2-1
(5)	" " " "	1-2-1, 1-2-1
(6)	" " " "	1-2-2, 1-2-2
(7)	" " " "	1-1-2, 1-1-2
(8)	" " " "	2-1-2, 2-1-2
(9)	" " " "	2-1-1, 2-1-1
(10)	" " " "	2-2-1, 2-2-1
(11)	" " " "	1-2-1-2, 1-2-1-2

etc.

The different apparatus of this system can be timed so as to show the flashes and the long and short darks at the same intervals of time, thus affording perfect uniformity and simplicity. The system is capable of producing an ample number of variations without going beyond four-group flashes.

In most instances the group numbers of both the flashes and colored bands at a tower can be the same.

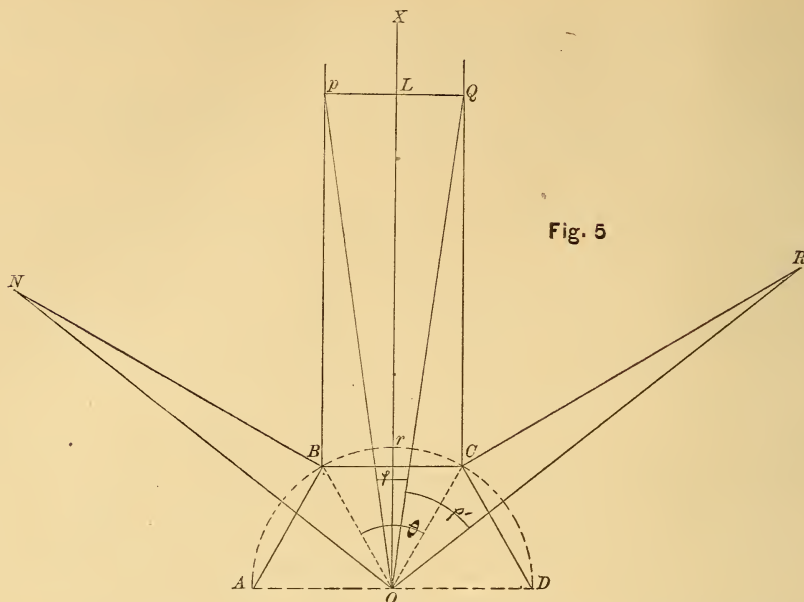


Fig. 5

## III.

## RELATIVE DURATION OF FLASHES AND ECLIPSES IN REVOLVING LIGHTS.

Let  $ABCD \dots$  be the plan of a portion of a flashing lens apparatus of any number  $n$  of sides, the flashes and eclipses being produced by the revolution of the whole apparatus about its axis at  $O$ .

On the line  $OX$ , perpendicular to  $BC$ , take  $L$  at any distance  $x$  from the light.

Draw  $BP$  and  $CQ$  perpendicular to  $BC$  and  $CR$  perpendicular to  $CD$ . Draw through  $L$  a parallel to  $BC$  and from  $P$  and  $Q$  where it intersects  $BP$  and  $CQ$ , draw  $PO$  and  $QO$ . Also take  $OR = OQ$ .

Then  $PBCQ$  will be part plan of one of the spaces covered by the flashes, and  $QCR$  part plan of one of the spaces covered by the eclipses as the apparatus revolves about its axis. This, of course, supposes the light at  $O$  to be concentrated in a point.

Let  $\theta = \angle BOC = \frac{360^\circ}{n}$ , and  $\phi = \angle POQ$  be any angle interval of the flash at any point. Also let  $\phi' = \angle QOR$  be the corresponding angle interval of the eclipse. The angle  $\angle BOC = \angle QCR = \angle POR$ ,

$$\text{or,} \quad \theta = \phi + \phi' \quad \dots (1)$$

From triangle  $POL$ , we have  $\tan.$   

$$POL = \frac{PL}{OL}.$$

Placing  $a$  for  $PL = \frac{1}{2}PQ = \frac{1}{2}BC$ , and representing  $Lr$  by  $x'$  and  $Or$  by  $R$ ,  $Or$  being the radius of the apparatus  $= OC$ , we have

$$\tan. \frac{1}{2}\phi = \frac{a}{x} = \frac{a}{R+x'} \quad \dots (2)$$

From (1) we have

$$\phi' = \theta - \phi \quad \dots (3)$$

From (2) it appears that as  $x$  increases,  $\phi$  decreases until  $x = \infty$  when  $D = 0$ .

When  $x = R$ ,  $\tan. \frac{1}{2}\phi = \frac{a}{R}$ , and  $\phi = \theta$ .

From (3) it is evident that when  $\phi = 0$ ,  $\phi' = \theta$ , and when  $\phi = \theta$ ,  $\phi' = 0$ .

From (2) and (3) we can obtain the value of  $\phi$  and  $\phi'$  at any distance by assuming  $x$ , when the dimensions of the apparatus are known.

The values of  $\phi$  and  $\phi'$  in seconds of time, or the duration of the eclipse and flash, at any distance from the light, can be obtained by applying to the deduced values the ratio between arc and time, when  $n$  and the time of a complete revolution are known. It will be seen from the foregoing discussion, that the duration of the flashes and eclipses of any revolving light varies with the distance of the observer from it, and that the proper method of observing these intervals is to estimate from the begin-

ning of a flash to the beginning of the one next following, or, from the middle of a flash to the middle of the next following. Also, that any reference to the duration of a flash or eclipse should be accompanied by a statement of the distance. A good expression for characterizing the time feature of revolving lights would be: Flashes commence at intervals of \* \* \*

## IV.

## VERTICALLY PROJECTED LIGHT.

If a lens were so arranged as to throw a portion of the light as a vertical, or nearly vertical, beam, this beam would probably be visible at very great distances, especially in thick or cloudy weather, when the rays would be reflected from the vapor particles at great elevation.

## CERTAIN DISCREPANCIES IN THE COMPUTATION OF THE POST TRUSS.

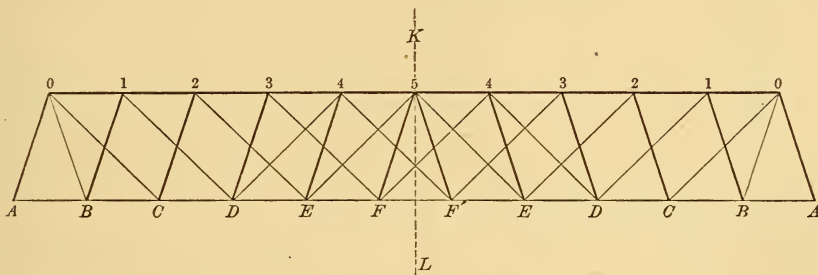
By CHARLES H. TUTTON.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

An application of the Graphical Analysis presented by the writer, in this Magazine for Nov., 1877, to the truss below represented, yields some curious facts. In order to avoid diagrams, which any one may construct by paying attention to that article, the results given in this article are arrived at by a calculation

exactly in accordance with the graphical method. To show the discrepancies more clearly, I will take a strain sheet of the Watson Mfg. Co. calculated from their data, and place their results side by side with those obtained in accordance with the graphical method.

It may be proper to state, however,



that from the compound nature of this truss all results must be based on certain suppositions. As the writer cannot agree with Col. Merrill and others who treat the inclined posts as counter braces, the supposition employed will be that the truss may be divided into two simple systems. Considering the truss loaded and the load moving off to the right, the braces, and, in fact all of the truss on the right of the center except the post 5F' is common to both systems. On the left, the first system is composed of posts 5F, 3D, 1B, 0A and connecting

braces, and the second of posts 5F', 4E, 2C, 0A and connecting braces. The loading and dimensions are as follows:

Height of truss, 28'6"; No. panels, 11; length of panels, 19.0 ft.; dead load per foot (two trusses), 950 lbs. = 475 per truss; live load per foot (two trusses), 2240 lbs. = 1120 per truss; panel weights per truss, dead, 9025 lbs.; live, 21,280 lbs. By the method of procedure employed in the Graphical Analysis, before referred to, we find the following resulting strains:

## STRAINS IN LOWER CHORD.

AB = 50510 lbs.	Watson	50510
BC = 101020 "	"	101020
CD = 171732 "	"	171734
DE = 242444 "	"	242448
EF = 272749 "	"	272754
FF' = 303054 "	"	303060

## IN UPPER CHORD.

01 = 141426	Watson	141428
12 = 222240	"	222244
23 = 262647	"	262652
33 = 303054	"	303060

Showing so far no discrepancy.

## STRAINS IN DIAGONAL TIES.

0B = 95824	Watson	95823
0C = 85702	"	85714
1D = 88438	"	85714
2E = 48322	"	51068
3F = 53794	"	56542
4F' = 16423	"	27370
5E = 27352	"	27370
4D = 3650 = 16411 before "		16422

countering.

## STRAINS IN POSTS.

0A = 159707	Watson	159705
1B = 65922	"	63882
2C = 36022	"	38061
3D = 40098	"	42141
4E = 12243	"	20400
5F = 20389	"	10200

It will be observed that there is a great discrepancy between these results in the web members especially at the center of the truss.

These results are derived from the supposition that when the truss is uniformly loaded, the strain through braces 0B and 0C are at their maximum and the load passing off relieves them, as in the Graphical Analysis.

It shows that when the load throws the maximum strain on 5E that the vertical force at 5, instead of being divided equally between posts 5F and 5F', sends through 5F' only  $\frac{1}{n}$  of a panel weight

( $n$  being the number of panels in the truss) of live load, while all of the remaining stress passes through post 5F.

As to the correctness of this method, it is left to others to judge. It is given here, as I was informed once of a bridge failing under circumstances which this view would indicate as possible, and I regret that I have mislaid the paper which contained its locality.

Referring again to the article quoted, it is but justice to state that the method then employed, and the combination of different loads in one general reaction or "force polygon," was suggested to me by seeing some lectures of Prof. Chas. McMillan, now (I believe) of Princeton College, N. J., and the method was not given as original with myself, but as an improvement (fancied so at least) over already existing, though so far as I am aware, unpublished methods. He also pointed out its generality of application in 1874.

The modification suggested by Prof. Fletcher in *Engineering News* for Jan. 17, 1878, has been employed by myself and others for nearly a year preceding the publication of the article. It was given as a purely graphical method, leaving out many simplifications which were self-evident, in order to make the "modus operandi" clear to a beginner as well as to the more proficient.

THE *Lifeboat Journal* thinks the time has come for a revision of the night signals established by the Merchant Shipping Act, 1873, and defines the principles which, it thinks, should be kept in view in any such revision, in the following sentences:

"(1) It is indispensable that signals of distress should be few in number, and readily distinguishable from all other signals, especially those shown in the night, since persons having to interpret them on the land would, in general, have no code of signals to refer to, but would have to trust their memories alone.

"(2) They should not be of an expensive or unwieldy character, or of a kind requiring skillfulness in their use, or they would not be available for all classes of vessels.

"(3) It would be desirable, as far as possible, to utilize articles already on board rather than to provide new ones unavailable for any other use."

## PLOWING BY STEAM.

By D. D. WILLIAMSON.\*

Contributed to VAN NOSTRAND'S MAGAZINE.

PERHAPS no branch of engineering has been more fascinating to mechanical engineers than that of steam plowing. The thought of inventing an implement which would supersede the common plow and revolutionize a process which is older than Christianity itself has, for many years, stirred the hearts and brains of ingenious men and incited them to patient labor and extraordinary effort. None have struggled more with this problem or met with greater disappointment than American engineers. The cheapness of our prairie land; the size of our farms; their natural adaptation to steam cultivation; the high cost and uncertainty of labor and many other reasons made it appear probable that this country would bring forth the steam plow and perfect it. The records of the Patent Office show how many men thought they had accomplished it. The fact that, in the year 1870, not a steam plow was practically working in the country proved the value of these patents. From among the many steam plows which were actually tried, and which gave promise of success, the Fawks and the Locher were perhaps the best. Fawks anticipating the prime trouble of all traction engines, viz; that of keeping the driving wheels from being buried by the weight of the engine whilst passing over soft ground, adopted the novel idea of using one driving wheel the entire width of his engine, and to facilitate its turning, shaped this long roller like a barrel, having the outer ends of less diameter than the center. The engine seems to have progressed fairly on dry ground and drew several plows which were hung from a gallows frame in the rear. Inability to generate steam sufficiently, which is the second grand difficulty with traction engines, prevented any continuous plowing. Before the engine could get across the field the incapacity of the boiler would bring the whole to a stand still. The barrel-shaped driving wheel

or roller, proved of no use in wet clay. To gain adhesion and prevent its useless revolving as it slipped in the wet soil, stout battens or strips of wood were fastened to the face of the roller so as to grip the earth and prevent the slip. These, however, held so well that the engine had not power enough to turn them. To have gained greater power would have necessitated increased weight and the weight was already sufficient to bury the engine hopelessly at almost every trial. The experiment was, therefore, abandoned. From later experience it is evident that Fawks had only just entered upon his troubles, for he had not worked his system sufficiently to develop the crowd of difficulties which awaited him.

Locher chose a much more favorable field for his operations, viz; the dry soil of California. His engine was more of the usual type of Traction engines, and was fitted with compensating gear which enabled it to turn whilst drawing its load. The details of the engine were, however, very rough. The special feature was the revolving diggers which worked behind, and which were driven from the same shaft as the driving wheels. It was claimed that these diggers helped very materially to propel the engine over the ground. The style of cultivation was, however, very peculiar and raised the objection that the huge clots of earth which were thrown from the diggers were not pulverized, and, consequently, the field was not in a condition to receive the seed. Although Locher deserves great credit for his ingenuity, the early abandonment of his machine was an evident sign of its unfitness for its work. It would have been interesting to have had some trials with the revolving diggers in soft earth. The presumption is that the engine would have stood still whilst the diggers would have dug a trench in which the whole would have settled. Of the more recent attempts may be mentioned, the Parvin motor which was simply the Boydel system

\* Read before the New York Society of Practical Engineering.

tem, which had been tried and abandoned in England many years ago. Traction was obtained by an engine mounted on a revolving platform, not unlike in appearance to a portable horse power. A series of slats of wood the width of the engine and separated a few inches from each other secured to endless chains, revolved over drums at each end of the engine, and slowly moved the same. The friction was, however, enormous, and the power required to move the large bearing surface which was in contact with the earth, proved, as in Boydell's experiments, out of all proportion to the total power, and, consequently, left too little power for useful work. The plows were arranged in a frame at the rear of the machine somewhat like Fawks. So small an amount of plowing was done by this system that no record is left of the manner in which it overcame the difficulties of continuous plowing. Boydell had hauled plows quite successfully so long as all the conditions were favorable for his machine, but when the question of expense, the quickness of turning, the unevenness of the ground, and the *breakage* were taken into account, the impracticability of the machine was so apparent that it was abandoned. As Parvin's was no improvement on the Boydell system its life seems to have been quite as brief.

The Redmond engine which is a copy of the Bray engine, also patented and abandoned in England many years since, depends for adhesion upon diggers which are pushed out from the center of the drivers and then withdrawn as the wheel revolves, very much like the patent buckets of some of the English side wheel steamships. With the ground just in the right condition they work well enough, but if the soil was hard the whole engine walked on its rim tip-toes very much to their damage. With soft earth the toes or diggers quickly dug holes under the driving wheels until the engine sat upon the ground, when all traction ceased. It was proposed by Redmond to draw some kind of a gang plow behind his engine. The only experiments made public were those in which several men held ordinary plows which were hitched to the engine as to a horse, and which were drawn across the field, but not turned.

There may have been other systems, but it is believed that the foregoing comprises the best of those which were actually in the field.

Dudgeon, Fisher and others had produced quite successful light traction engines which ran well on McAdamised roads, but none of them were designed for the more difficult work of plowing. The great question of maintaining adhesion on slippery fields—of working in soft earth—of keeping up steam to a full working pressure during the entire day—of carrying supplies of fuel and water—of durability—of accurate steering and rapid turning, had scarcely been entered upon by any of those whose attempts have been named. Naturally with the spasmodic efforts of the engine the great problem of the construction of suitable plans had no chance of solution. The failure of the engines had precluded the necessity for attacking the question of the work they were to do, and engines and plows went down into a common grave together. In the year 1869, I saw a Thomson Road Steamer, with its broad rubber tires draw a train of heavily loaded wagons over a soft wet field in Scotland. I rode upon the engine when it drew the same load through the yielding deep sands on the shore of the Firth of Forth, and when it climbed the steep, slippery streets of the old town of Edinburgh. I spent many days with it striving to find a fault with its peculiar tire, but the more I examined its workings the more I was convinced that its camel-footed, elastic tread solved the great question of maintaining its footing, whilst working in soft soil and drawing plows behind it. Having arranged for the right to work under the American Patents, I imported an engine from Scotland in 1870, and commenced a series of experiments with it. Whilst the rubber tire did all and more than I had expected, I found the difficulty of maintaining steam a most serious drawback. Calling to my aid some of the best engineering talent in the country, I succeeded, in 1871, in producing what was afterwards known as the "Williamson Road Steamer and Steam Plow." The engines were built by the Grant Locomotive Works of Paterson N. J., and were far ahead of anything which had been attempted before in either

hemisphere. Boilers, shafts and gearing of steel, and the exactness in workmanship of the finest express locomotives, gave them the perfection of strength with the minimum of weight. With all the costly experience of the past four years it can be safely said that no more perfect engines could be produced to-day. With their peculiar boilers steam was made with such rapidity that no difficulty was found in maintaining it at 120 lbs. pressure, with the valves wide open and the engines making 300 or 400 revolutions per minute. A brief description of the engine as finally completed may be of interest.

The entire engine which was only 13 feet long by 6 wide, was mounted on three wheels. The drivers which were so placed as to take nearly the whole weight were six feet in diameter, with a tread of 12 inches. The third wheel was about half the size of the drivers, placed at the extreme front in a fork, and being worked by a sector and uneven wheel steered the engine with perfect accuracy and with very little effort. All three wheels had tires of a peculiarly compounded and vulcanized india rubber, made in a single ring 12 inches wide and 5 inches thick. Side flanges prevented these from slipping off, whilst a great number of holes in the tread of the wheel into which the rubber was forced, as the weight was upon it, prevented in a great measure their slipping around. Outside of this rubber tire was a chain of endless steel plates which revolved with the wheel and which sinking into the rubber as it came in contact with the ground preserved it from all harm. It may then be properly mentioned that whilst many supposed that the rubber would be quickly worn out, no difficulty was ever found on that point, and a set of tires which had run in hard work over all kinds of roads and fields, over 3,000 miles, when taken off and examined were scarcely marked, and there was no reason to doubt but that they would outlast the boiler and engines.

The vertical boiler which was of steel, was 3 feet in diameter with 120—1½ inch tubes, and with the most perfect proportion of water and steam space. It supplied steam to two 6×10 inch cylinders, the valves of which were

wrought with a link. The throttle valve and reversing handle were within handy reach of the engineer as he worked the steerage. On the crank shaft was a pinion which geared into a spur wheel on an intermediate shaft, and on the ends of the latter shaft were sliding clutch pinions which engaged racks bolted to the inside of the drivers. These clutch pinions were worked by handles at the side of the engineer's seat. The crank shaft was provided with the same arrangement of clutch pinions, thus giving the engine two speeds. The quick speed which was about 6 miles per hour, was for road service—the drivers turning once to every six revolutions of the engine. The slow speed for plowing was 2½ to 3 miles, requiring 18 revolutions of the crank shaft to 1 of the drivers. The latter gave the enormous tractive force of about 8000 lbs., equal to that of say 40 horses. Either driving wheel could by the same handles be entirely disengaged, so that the engine could turn in its own length. Tanks which hold 300 gallons of water and bunkers containing half a ton of coal were conveniently disposed. The weight of the engine was six tons, and whilst ample strength was secured, there was not a superfluous fund of metal. This is an important statement, for it is a common belief that a traction engine for drawing plows, can be made as light as a fire engine.

Two of the engines were sold to parties in Great Britain and are being worked as road engines. Being of American build they have naturally been very closely criticised, and it has been freely conceded that no such perfect engines have been made in that country.

A number of plows were tried. The latest of which made after two years of hard experience, consisted of six steel plows on a diagonal beam mounted on a cranked axle. One wheel on this axle ran in the furrow and the other on hard ground. A small swivel wheel in front kept the whole steady. A lever on the axle which was operated by a rope leading to the fireman at the rear of the engine engaged the plows or threw them out of action immediately. The plows were also adjustable to run at any depth. They were hinged on the beam, and secured by a brace having a safety pin

of known strength. In case of striking a bowlder or land-fast stone the safety pin broke and the plow turning back on its hinge escaped all injury. The time lost in remedying such a break was not over one minute and the cost not over a couple of cents. During the first year's experience every such accident cost a plow.

The breaking plows were attached loosely to a triangular carriage, and having broad soles did not need the rigid connection necessary for stubble plows. As soon as the engine started each plow took its line of draft and turned its sod, 20 inches wide, and often 30 feet long without a break. One of the main objects of this loose connection was to enable a plow to be immediately detached in order to sharpen it. It required the services of one man to sharpen the plows, and there being extra plows the full number of five were always at work. No better sight could be offered a farmer than to see these fine green waves following in the wake of the steamer.

The first really great achievement of the Williamson Steam Plow was in the testing trials of one sold to Col. Thompson of Minnesota, when with a gang of five 20 inch breaking plows, it actually plowed four acres in an hour of virgin prairie. The power exerted may be estimated from the fact that a 20 inch breaking plow is usually drawn by four yoke of oxen, and the amount plowed is not over an acre per day. Of course the four acres per hour was an extreme amount, but Col. Thompson afterwards reported 30 acres per day of 10 hours as being the regular work of the engine. One of the engines was taken by Messrs. Landreth & Sons, on their celebrated seed farm in Pennsylvania. The peculiarity of their special crops required a continued shifting of their work, and the ability of the engine with its plows to go from one field to another was of great importance. In addition to the plow furnished with the engine, the Messrs. Landreth constructed a very ingenious cultivator for stirring the sub-soil without turning it up. It worked admirably, thoroughly breaking up the hard pan and loosening the soil to a depth of 14 inches. It made a heavier draft on the engine than did the gang plow.

They also used their engine for drawing manure from their docks on the Delaware to the fields, taking up to 9 tons at once. In other parts of the country they were introduced with every prospect of success. Difficulties which arose were mostly overcome and it was believed that their permanent success was assured. The rubber tires worked to a charm, and so long as the ground was dry enough for horses to plow the steamer would hold its own. The turning at the ends of the field was by practice reduced much below that accomplished by teams in actual competition. But now came a new test—that of plowing loose soil which had been baked to a dry powder by the fierce heat of our summer sun. And here is where an entirely new and fatal objection arose which had never before presented itself. The *dust*, which was stirred up and scattered by the driving wheels combined with that made by the plows, enveloped everything so that the engine moved in a dense cloud. The driver and fireman could not be recognized. The "dust-tight" joints of the engine covers proved of no avail, and instead of ten hours of work being accomplished per day in plowing, but one half were so occupied, whilst the other five were required for cleaning the engine. Even this division of time was not the only loss, for the engines were cutting themselves to pieces and every bearing, however well guarded, was heating and wearing. After fighting the dust bravely for a long time, trying in every way to protect the machinery from its disastrous effect, it became evident that the objection was to a certain extent fatal. The same difficulty would present itself every year in most parts of the country. This, coupled with difficulties inherent in any system of steam plowing, and which will be noticed hereafter, caused the reluctant abandonment of the enterprise. The engines and plows had abundantly accomplished all and more than had been expected of them at the time they were built, but they had also, unfortunately, developed the fact that there were not enough farmers in this country able to purchase such very expensive machinery to create a demand large enough to make their construction a profitable business, even if the dust difficulty and other

objections could by further experiment be overcome. To be sold at reasonable rates the engines would have to be made in series of at least ten at one time, for there was much more work upon them than on locomotives.

It may be asked why confess that the hard work of five years and the expenditure of so many thousands of dollars had resulted in a partial failure? One answer is that many of the objections could not be seen at the start, and indeed required all that time and money to develop them. Another answer is that every engineer or manufacturer, engaged in so important an enterprise as steam plowing owes it to the hundreds of ingenious inventors who may follow him to give the results of his experience, be they successes or failures. In no other way will coming men take up the work where others leave off, but they will go over the same ground, which will lead only to disappointment and loss. No other American ever built ten engines, or had such a large experience. Never did engineers and agriculturalists of such ability assist so heartily to command success, and in no country were the trials conducted with more perseverance and conscientiousness.

Plowing by direct traction not being suitable for all conditions of soil, it may be asked whether the English steam plowing system is adapted to this country. My answer is that it may answer admirably under certain conditions, but that it is impractical for the *average* American Farmer.

A brief description of the English system, the working of which I carefully inspected in England during the last plowing season, must first be given. Among the many different systems all, however, based upon rope traction, which have been before the British public for the last five years, the only two which are now considered practical are the "direct tackle," being a traction engine on each side of the field which move along on the headlands and wind up a wire rope to which the plow is attached, and the single engine "tackle" where the engine generally remains stationary, in one corner of the field, whilst two "traveling anchors" move along the headland and between which the implement works back and forth.

The first mentioned requires at least five and often seven hands and four horses, and could not be laid down on a farm in America for less than \$12,000 to \$15,000 cash. The second is worked with one or two hands less, and would cost about \$6,000 to \$7,500 when ready for work. It, however, requires a much longer time to set to work and to take up than the double engine system.

The traction engines used with the direct tackle are very large and powerful, weighing from 15 to 20 tons each. They are fitted with winding drums under their locomotive boilers, which are driven by bevil gears from the crank shaft. A clutch throws the road gear into action, and the engine moves just the width of the plows and stops. The winding drum then revolving draws the plow towards it. Meanwhile the engine on the opposite headland moves into position and in turn draws the plow on its return "bout." The plow which is very heavy and cumbersome, consists of two diagonal beams balanced on a pair of wheels. On one beam are the right hand plows, and on the other the left hand plows. It has the advantage of leaving no dead furrows. It has, however, no provision for avoiding a breakage in case of meeting land-fast stones. Two boys, stationed at proper distances from each other, place rope porters or pullies under the running rope to keep it from the ground. These are removed as the plow nears them, and they are placed in position again as soon as the plow has passed. In case of wide or uneven fields more boys with porters are necessary, as the wire rope especially in gritty soil suffers from attrition.

The single engine system consists of one traction engine which can either travel on one headland with a traveling anchor opposite, or what, is still better, in many fields can be placed stationary in one corner of the field. From its fly wheel a belt drives a windlass which winds and unwinds on two drums the wire rope. The latter passes around two traveling anchors which move automatically along the headlands, with the plow working between them.

There are also sets of tackle worked by a portable engine, but these accomplish but little work. An engine which will do a fair amount of work is too

powerful and heavy to be hauled about with horses—it must be self-moving. All the rope tackles waste a great deal of power by friction. The weight of coal expended per acre is exactly the same as that used by the Williamson system, when the engine travels across the field. The reasons why I think the English system is not suited for this country are deduced from actual experience, in connection with my own engines, and many of which will apply to any system yet proposed. They are:

1st. Their excessive cost. Very few farmers in this country can afford to pay out \$7,500 to \$15,000 in cash for a single implement.

2d. The shortness of the plowing season here would make it possible only to use this expensive machinery about one third of the year.

3d. On account of the important place Indian corn occupies in our crops, for the cultivation of which horses are necessary, the dispensing with horses (which should be one of the advantages of the steam plow) could not be accomplished. To have a stable full of horses standing idle whilst the steam plow was at work would scarcely be economical.

4th. In many of the States, especially in the West, the long dry summers produce a scarcity of water, and often stock must be driven long distances to water. In such districts it would be impossible to procure the 1,000 to 2,000 gallons which would be required daily. The ordinary barn-yard well would be altogether inadequate. (In Minnesota the water for the Williamson plow was carted a distance of over four miles).

5th. Good engineers cannot be hired for short terms of service. In England, where there is always a surplus of such skilled labor, it is possible to engage them at short notice for only the plowing season. Few good men would leave our cities to go far into the country for only three months. The wear and tear on the machinery is very considerable, and competent engineers must be employed who can keep their engines in repair.

5th. Our distances are too great and our season too short to make the co-operative system practicable. Every farmer would want the steamer at the same time. The enormous weight of

the English engine would require all the usual bridges to be strengthened, and this would make their removal from one farm to another excessively expensive.

Lastly, plowing by the English system, while it is very thorough, costs as much if not more than by horses. Nothing can compete with oxen, for they can be worked until the season is over, and then fattened and eaten. The double engine system, which gives the most economical results, requires generally seven hands and four horses, (the latter for hauling water), and the implement used is a fine gang plow. The cost of the above force (taking into account the extra pay of engineers) would equal 5 plows, with one man and two horses to each. It is true that the latter 5 plows would not accomplish as much as the former, but the difference would not compensate for the ton of coal, the interest and the wear of engines and wire rope. The report of a committee appointed to examine the depreciation of the wire rope, stated it to be 7 pence sterling (about 15 cents currency) per acre.

The double engine system imported by Mr. Lawrence for his sugar plantation in Louisiana, and said to have cost \$20,000, drew a single plow which cut a furrow 3 feet deep. This was certainly very wonderful plowing, and gave a large increase in the crop, but not great enough to make it pay. Another, set on a neighboring plantation, was abandoned as being unprofitable. During the two years when the duty was removed from steam plows to encourage their importation, few if any were imported, although many intelligent farmers had visited England to inquire into their working. At present they must pay a duty of 35 per cent. In Cuba they proved, as in Louisiana, a mechanical success, but they did not reduce the number of Negroes and mules. When used to clear the fields of cane, they set fire to the dry leaves and spread destruction through several plantations. The question of fire is a most serious one in all dry countries.

There are many reasons why no comparison can be made between the use of the steam plow in Great Britain and in America. These differences should be well studied both by inventors and pur-

chasers who may read only of their success in England.

In Great Britain horses and horse feed are much dearer than with us, and the use of oxen is by law forbidden. Coals, engineer's wages, and interest are less than here, and wells a hundred times more abundant. The notoriously wet climate of England makes plowing much more difficult than with us; and every American traveling there is surprised to see three or four immense horses in tandem before a single plow, and accomplishing but about an acre per day. These heavy horses, treading in each others steps in heavy wet clay for many years, eventually pack the soil into a hard pan, through which the roots of the plants cannot penetrate, and to break up this hard pan their peculiar steam cultivator, an implement here, is invaluable.

In England and Scotland the plowing season is longer than with us, and for that reason a neighborhood can club together and buy a steam plow; with us the time for plowing is so short that all would want it at the same time.

The conclusion of all this is, that those who may be ambitious to invent a steam plow have now no excuse for wasting time or money. It used to be said that former attempts in America had not been successful because the engines were too cheaply constructed. "They were built in country machine shops and did not combine all the modern improvements. They were run by men who knew more about agriculture than about engineering, and that, owing to very limited means, no advantage could be taken by those who had failed to follow up their experience by constructing new and improved engines." This argument no longer obtains. Until radical changes are made in railway locomotives, there can be no important improvement on the dozen of Williamson engines which have been worked in as many different states of the Union. Especially must the idea be abandoned that a serviceable engine can be made to weigh only two or three tons. It must be borne in mind that a steam plow should be able to plow at least one acre per hour. One of the largest builders of plowing machinery in England informed me that he could not recommend the use of steam, unless of sufficient power to accomplish that

amount of work. This represents the constant work of twenty horses; but it must be remembered that a horse can for a short time exert twice his average pull, and that occasions for this extra work present themselves constantly in plowing, although lasting perhaps for but a few moments at a time. There must be therefore an amount of extra power always at command, so that the opening of a valve wide will at once save a stoppage. Nothing is more demoralizing in steam plowing than continual stoppages. The production of this amount of power requires boilers and engines of suitable size, and the suddenness with which this power is called for requires all connections to be of extraordinary strength. The boiler must always have enough water, and, to ensure this, there can be no liberty taken in cutting down the size of water tanks. These in turn must have coal bunkers of corresponding size. By the time the whole engine has been built in true proportion it will be found to weigh at the *very least* six tons. The engines exhibited by Messrs, Fowler at the Oxford Show weighed 20 tons each.

In the matter of plows it must be remembered that the latest plows, both for stubble and for breaking prairie, as perfected for the Williamson system left nothing to be desired. They were not expensive; were strong, and the work they did was pronounced perfectly satisfactory. No system of rotary plowing has yet been successful, or even if successful, it is not believed that it could supersede the modern plow.

Those who wish to avail themselves of the English system, must carefully consider the following points: The implement used mostly by the British is the steam "Cultivator," an instrument made necessary by their climate, soil and centuries of cultivation. It has taken many years to perfect it for the special crops for which it is used, and for the comparatively even conditions of climate, &c. It will be found that many of these conditions are totally different here, and that what may prove advantageous there, may be quite the reverse with us. The water question is of the most serious importance, much more so than would appear to those who had not experienced it.

The amount of work done must not be estimated from the short "spurts" which are accomplished by trained hands with new engines at agricultural shows, but should be based upon the week's work of a well-managed farm.

All honor be to English engineers who have done so much for British agriculture, and all honor be to those Americans who, finding *all* their conditions the same as those of their British cousins, have the enterprise to order out these expensive improvements, and thus, like true Republicans, use their intelligence and

means for the benefit of their fellow men.

For myself, standing at the end of a five year's effort, with enthusiasm tempered by costly experience, with an earnest desire for substantial improvements, but with an equally serious respect for solemn facts, and with a view extending over the whole field, I am constrained to give it as my opinion, that no system of steam plowing yet invented can offer sufficient inducement to make it an object for the average American Farmer to adopt.

## MATTER AND MOTION.

By J. CLERK MAXWELL, LL.D., F.R.S.

### I.

#### CHAPTER I.

#### INTRODUCTION.

**NATURE OF PHYSICAL SCIENCE.**—Physical science is that department of knowledge which relates to the order of nature, or, in other words, to the regular succession of events.

The name of physical science, however, is often applied in a more or less restricted manner to those branches of science in which the phenomena considered are of the simplest and most abstract kind, excluding the consideration of the more complex phenomena, such as those observed in living beings.

The simplest case of all is that in which an event or phenomenon can be described as a change in the arrangement of certain bodies. Thus the motion of the moon may be described by stating the changes in her position relative to the earth in the order in which they follow one another.

In other cases we may know that some change of arrangement has taken place, but we may not be able to ascertain what that change is.

Thus when water freezes we know that the molecules, or smallest parts of the substance, must be arranged differently in ice and in water. We also know that this arrangement in ice must have a certain kind of symmetry, because the

ice is in the form of symmetrical crystals, but we have as yet no precise knowledge of the actual arrangement of the molecules in ice. But whenever we can completely describe the change of arrangement we have a knowledge, perfect so far as it extends, of what has taken place, though we may still have to learn the necessary conditions under which a similar event will always take place.

Hence the first part of physical science relates to the relative position and motion of bodies.

#### DEFINITION OF A MATERIAL SYSTEM.—

In all scientific procedure we begin by marking out a certain region or subject as the field of our investigations. To this we must confine our attention, leaving the rest of the universe out of account till we have completed the investigation in which we are engaged. In physical science, therefore, the first step is to define clearly the material system which we make the subject of our statements. This system may be of any degree of complexity. It may be a single material particle, a body of finite size, or any number of such bodies, and it may even be extended so as to include the whole material universe.

**DEFINITION OF INTERNAL AND EXTERNAL.**—All relations or actions between one part of this system and

another are called Internal relations or actions.

Those between the whole or any part of the system, and bodies not included in the system, are called External relations or actions. These we study only so far as they affect the system itself, leaving their effect on external bodies out of consideration. Relations and actions between bodies not included in the system are to be left out of consideration. We cannot investigate them except by making our system include these other bodies.

**DEFINITION OF CONFIGURATION.**—When a material system is considered with respect to the relative position of its parts, the assemblage of relative positions is called the configuration of the system.

A knowledge of the configuration of the system at a given instant implies a knowledge of the position of every point of the system with respect to every other point at that instant.

**DIAGRAMS.**—The configuration of material systems may be represented in models, plans, or diagrams. The model or diagram is supposed to resemble the material system only in form, not necessarily in any other respect.

A plan or a map represents on paper in two dimensions what may really be in three dimensions, and can only be completely represented by a model. We shall use the term Diagram to signify any geometrical figure, whether plane or not, by means of which we study the properties of a material system. Thus, when we speak of the configuration of a system, the image which we form in our minds is that of a diagram, which completely represents the configuration, but which has none of the other properties of the material system. Besides diagrams of configuration we may have diagrams of velocity, of stress, &c., which do not represent the form of the system, but by means of which its relative velocities or its internal forces may be studied.

**A MATERIAL PARTICLE.**—A body so small that, *for the purposes of our investigation*, the distances between its different parts may be neglected, is called a material particle.

Thus in certain astronomical investigations the planets, and even the sun, may be regarded each as a material particle, because the difference of the actions of different parts of these bodies does not come under our notice. But we cannot treat them as material particles when we investigate their rotation. Even an atom, when we consider it as capable of rotation, must be regarded as consisting of many material particles.

The diagram of a material particle is of course a mathematical point, which has no configuration.

**RELATIVE POSITION OF TWO MATERIAL PARTICLES.**—The diagram of two material particles consists of two points, as, for instance, A and B.

The position of B relative to A is indicated by the direction and length of the straight line  $\overline{AB}$  drawn from A to B. If you start from A and travel in the direction indicated by the line  $\overline{AB}$  and for a distance equal to the length of that line, you will get to B. This direction and distance may be indicated equally well by any other line, such as  $\overline{ab}$ , which is parallel and equal to  $\overline{AB}$ . The position of A with respect to B is indicated by the direction and length of the line  $\overline{BA}$ , drawn from B to A, or the line  $\overline{ba}$ , equal and parallel to  $\overline{BA}$ .

It is evident that  $\overline{BA} = -\overline{AB}$ .

In naming a line by the letters at its extremities, the order of the letters is always that in which the line is to be drawn.

**VECTORS.**—The expression  $\overline{AB}$ , in geometry, is merely the name of a line. Here it indicates the operation by which the line is drawn, that of carrying a tracing point in a certain direction for a certain distance. As indicating an operation,  $\overline{AB}$  is called a Vector, and the operation is completely defined by the direction and distance of the transference. The starting point, which is called the origin of the vector, may be anywhere.

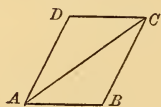
To define a finite straight line we must state its origin as well as its direction and length. All vectors, however, are regarded as equal which are parallel (and drawn towards the same parts) and of the same magnitude.

Any quantity, such, for instance, as a velocity, or a force, which has a definite direction and a definite magnitude may be treated as a vector, and may be indicated in a diagram by a straight line whose direction is parallel to the vector, and whose length represents, according to a determinate scale, the magnitude of the vector.

SYSTEM OF THREE PARTICLES.—Let us next consider a system of three particles.

Its configuration is represented by a diagram of three points, A, B, C.

FIG. 1.



The position of B with respect to A is indicated by the vector  $\overrightarrow{AB}$ , and that of C with respect to B by the vector  $\overrightarrow{BC}$ .

It is manifest that from these data, when A is known, we can find B and then C, so that the configuration of the three points is completely determined.

The position of C with respect to A is indicated by the vector  $\overrightarrow{AC}$ , and by the last remark the value of  $\overrightarrow{AC}$  must be deducible from those of  $\overrightarrow{AB}$  and  $\overrightarrow{BC}$ .

The result of the operation  $\overrightarrow{AC}$  is to carry the tracing point from A to C. But the result is the same if the tracing point is carried first from A to B and then from B to C, and this is the sum of the operations  $\overrightarrow{AB} + \overrightarrow{BC}$ .

ADDITION OF VECTORS.—Hence the rule for the addition of vectors may be stated thus:—From any point as origin draw the successive vectors in series, so that each vector begins at the end of the preceding one. The straight line from the origin to the extremity of the series represents the vector which is the sum of the vectors.

The order of addition is indifferent, for if we write  $\overrightarrow{BC} + \overrightarrow{AB}$  the operation indicated may be performed by drawing  $\overrightarrow{AD}$  parallel and equal to  $\overrightarrow{BC}$ , and then joining  $\overrightarrow{DC}$ , which, by Euclid, I. 33, is parallel and equal to  $\overrightarrow{AB}$ , so that by these two operations we arrive at the

point C in whichever order we perform them.

The same is true for any number of vectors, take them in what order we please.

SUBTRACTION OF ONE VECTOR FROM ANOTHER.—To express the position of C with respect to B in terms of the positions of B and C with respect to A, we observe that we can get from B to C either by passing along the straight line  $\overrightarrow{BC}$  or by passing from B to A and then from A to C. Hence

$$\overrightarrow{BC} = \overrightarrow{BA} + \overrightarrow{AC}.$$

$$= \overrightarrow{AC} + \overrightarrow{BA} \text{ since the order of addition is indifferent.}$$

$$= \overrightarrow{AC} - \overrightarrow{AB} \text{ since } \overrightarrow{BA} \text{ is equal and opposite to } \overrightarrow{AB}. \text{ Or, the vector } \overrightarrow{BC}, \text{ which expresses the position of C with respect to B, is found by subtracting the vector of B from the vector of C, these vectors being drawn to B and C respectively from any common origin A.}$$

ORIGIN OF VECTORS.—The positions of any number of particles belonging to a material system may be defined by means of the vectors drawn to each of these particles from some one point. This point is called the origin of the vectors, or, more briefly, the Origin.

This system of vectors determines the configuration of the whole system; for if we wish to know the position of any point B with respect to any other point A, it may be found from the vectors  $\overrightarrow{OA}$  and  $\overrightarrow{OB}$  by the equation

$$\overrightarrow{AB} = \overrightarrow{OB} - \overrightarrow{OA}.$$

We may choose any point whatever for the origin, and there is, for the present, no reason why we should choose one point rather than another. The configuration of the system—that is to say, the position of its parts with respect to each other—remains the same, whatever point be chosen as origin. Many inquiries, however, are simplified by a proper selection of the origin.

RELATIVE POSITION OF TWO SYSTEMS.—If the configurations of two different systems are known, each system having its own origin, and if we then wish to

include both systems in a larger system' having, say, the same origin as the first of the two systems, we must ascertain the position of the origin of the second system with respect to that of the first, and we must be able to draw lines in the second system parallel to those in the first.

FIG. 2.

P.

O.

O'.

Then by "System of Three Particles," the position of a point P of the second system, with respect to the first origin, O, is represented by the sum of the vector OP of that point with respect to the second origin, O' and the vector OO' of the second origin, O' with respect to the first, O.

**THREE DATA FOR THE COMPARISON OF TWO SYSTEMS.**—We have an instance of this formation of a large system out of two or more smaller systems, when two neighboring nations, having each surveyed and mapped its own territory, agree to connect their surveys so as to include both countries in one system. For this purpose three things are necessary.

1st. A comparison of the origin selected by the one country with that selected by the other.

2d. A comparison of the directions of reference used in the two countries.

3d. A comparison of the standards of length used in the two countries.

1. In civilized countries latitude is always reckoned from the equator, but longitude is reckoned from an arbitrary point, as Greenwich or Paris. Therefore, to make the map of Britain fit that of France, we must ascertain the difference of longitude between the Observatory of Greenwich and that of Paris.

2. When a survey has been made without astronomical instruments, the directions of reference have sometimes been those given by the magnetic compass. This was, I believe, the case in the original surveys of some of the West India islands. The results of this survey, though giving correctly the local configuration of the island, could not be

made to fit properly into a general map of the world till the deviation of the magnet from the true north at the time of the survey was ascertained.

3. To compare the survey of France with that of Britain, the meter, which is the French standard of length, must be compared with the yard, which is the British standard of length.

The yard is defined by Act of Parliament 18 and 19 Vict. c. 72, July 30, 1855, which enacts "that the straight line or distance between the centers of the transverse lines in the two gold plugs in the bronze bar deposited in the office of the Exchequer shall be the genuine standard yard at 62° Fahrenheit, and if lost, it shall be replaced by means of its copies."

The meter derives its authority from a law of the French Republic in 1795. It is defined to be the distance between the ends of a certain rod of platinum made by Borda, the rod being at the temperature of melting ice. It has been found by the measurements of Captain Clarke that the meter is equal to 39.37043 British inches.

**ON THE IDEA OF SPACE.**—We have now gone through most of the things to be attended to with respect to the configuration of a material system. There remain, however, a few points relating to the metaphysics of the subject, which have a very important bearing on physics.

We have described the method of combining several configurations into one system which includes them all. In this way we add to the small region, which we can explore by stretching our limbs, the more distant regions which we can reach by walking or by being carried. To these we add those of which we learn by the reports of others, and those inaccessible regions whose position we ascertain only by a process of calculation, till at last we recognize that every place has a definite position with respect to every other place, whether the one place is accessible from the other or not.

Thus from measurements made on the earth's surface we deduce the position of the center of the earth relative to known objects, and we calculate the number of cubic miles in the earth's volume quite independently of any hypothesis as to what may exist at the center of the

earth, or in any other place beneath that thin layer of the crust of the earth which alone we can directly explore.

**ERROR OF DESCARTES.**—It appears then, that the distance between one thing and another does not depend on any material thing between them, as Descartes seems to assert when he says (Princip. Phil., II. 18) that if that which is in a hollow vessel were taken out of it without anything entering to fill its place, the sides of the vessel, having nothing between them, would be in contact.

This assertion is grounded on the dogma of Descartes, that the extension in length, breadth, and depth which constitute space is the sole essential property of matter. "The nature of matter," he tells us, "or of body considered generally, does not consist in a thing being hard, or heavy, or colored, but only in its being extended in length, breadth, and depth" (Princip., II. 4). By thus confounding the properties of matter with those of space he arrives at the logical conclusion, that if the matter within a vessel could be entirely removed the space within the vessel would no longer exist. In fact he assumes that all space must be always full of matter.

I have referred to this opinion of Descartes in order to show the importance of sound views in elementary dynamics. The primary property of matter was indeed distinctly announced by Descartes in what he calls the "First Law of Nature" (Princip., II. 37): "That every individual thing, so far as in it lies, perseveres in the same state, whether of motion or of rest."

We shall see when we come to Newton's laws of motion that in the words "so far as in it lies," properly understood, is to be found the true primary definition of matter, and the true measure of its quantity. Descartes, however, never attained to a full understanding of his own words (*quantum in se est*), and so fell back on his original confusion of matter with space—space being, according to him, the only form of substance, and all existing things but affections of space. This error runs through every part of Descartes' great work, and it forms one of the ultimate foundations of the system of Spinoza. I shall not at-

tempt to trace it down to more modern times, but I would advise those who study any system of metaphysics to examine carefully that part of it which deals with physical ideas.

We shall find it more conducive to scientific progress to recognise, with Newton, the ideas of time and space as distinct, at least in thought, from that of the material system whose relations these ideas serve to co-ordinate.

**ON THE IDEA OF TIME.**—The idea of Time in its most primitive form is probably the recognition of an order of sequence in our states of consciousness. If my memory were perfect, I might be able to refer every event within my own experience to its proper place in a chronological series. But it would be difficult, if not impossible, for me to compare the interval between one pair of events and that between another pair—to ascertain, for instance, whether the time during which I can work without feeling tired is greater or less now than when I first began to study. By our intercourse with other persons, and by our experience of natural processes which go on in a uniform or a rhythmical manner, we come to recognize the possibility of arranging a system of chronology in which all events whatever, whether relating to ourselves or to others, must find their place. Of any two events, say the actual disturbance at the star in Corona Borealis, which caused the luminous effects examined spectroscopically by Mr. Huggins on the 16th May, 1866, and the mental suggestion which first led Professor Adams or M. Leverrier to begin the researches which led to the discovery, by Dr. Galle, on the 23rd September, 1846, of the planet Neptune, the first named must have occurred either before or after the other, or else at the same time.

Absolute, true, and mathematical Time is conceived by Newton as flowing at a constant rate, unaffected by the speed or slowness of the motions of material things. It is also called duration. Relative, apparent, and common time is duration as estimated by the motion of bodies, as by days, months, and years. These measures of time may be regarded as provisional, for the progress of astronomy has taught us to measure the

inequality in the lengths of days, months, and years, and thereby to reduce the apparent time to a more uniform scale, called Mean Solar Time.

**ABSOLUTE SPACE.**—Absolute space is conceived as remaining always similar to itself and immovable. The arrangement of the parts of space can no more be altered than the order of the portions of time. To conceive them to move from their places is to conceive a place to move away from itself.

But as there is nothing to distinguish one portion of time from another except by the different events which occur in them, so there is nothing to distinguish one part of space from another except its relation to the place of material bodies. We cannot describe the time of an event except by reference to some other event, or the place of a body except by reference to some other body. All our knowledge, both of time and place, is essentially relative. When a man has acquired the habit of putting words together, without troubling himself to form the thoughts which ought to correspond to them, it is easy for him to frame an antithesis between this relative knowledge and a so-called absolute knowledge, and to point out our ignorance of the absolute position of a point as an instance of the limitation of our faculties. Any one, however, who will try to imagine the state of a mind conscious of knowing the absolute position of a point will ever after be content with our relative knowledge.

**STATEMENT OF THE GENERAL MAXIM OF PHYSICAL SCIENCE.**—There is a maxim which is often quoted, that “The same causes will always produce the same effects.”

To make this maxim intelligible we must define what we mean by the same causes and the same effects, since it is manifest that no event ever happens more than once, so that the causes and effects cannot be the same in *all* respects. What is really meant is that if the causes differ only as regards the absolute time or the absolute place at which the event occurs, so likewise will the effects.

The following statement, which is equivalent to the above maxim, appears to be more definite, more explicitly con-

nected with the ideas of space and time, and more capable of application to particular cases:

“The difference between one event and another does not depend on the mere difference of the times or the places at which they occur, but only on differences in the nature, configuration, or motion of the bodies concerned.”

It follows from this, that if an event has occurred at a given time and place it is possible for an event exactly similar to occur at any other time and place.

There is another maxim which must not be confounded with that quoted at the beginning of this article, which asserts “That like causes produce like effects.”

This is only true when small variations in the initial circumstances produce only small variations in the final state of the system. In a great many physical phenomena this condition is satisfied; but there are other cases in which a small initial variation may produce a very great change in the final state of the system, as when the displacement of the points causes a railway train to run into another instead of keeping its proper course.

## CHAPTER II.

### ON MOTION.

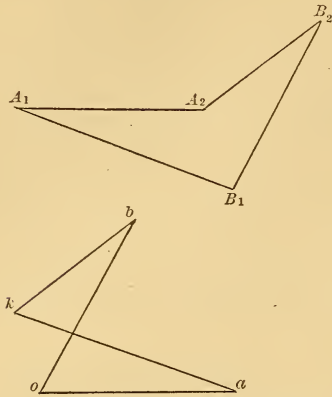
**DEFINITION OF DISPLACEMENT.**—We have already compared the position of different points of a system at the same instant of time. We have next to compare the position of a point at a given instant with its position at a former instant, called the Epoch.

The vector which indicates the final position of a point with respect to its position at the epoch is called the Displacement of that point. Thus if  $A_1$  is the initial and  $A_2$  the final position of the point  $A$ , the line  $\overline{A_1 A_2}$  is the displacement of  $A$ , and any vector  $\overline{o a}$  drawn from the origin  $o$  parallel and equal to  $\overline{A_1 A_2}$  indicates this displacement.

**DIAGRAM OF DISPLACEMENT.**—If another point of the system is displaced from  $B_1$  to  $B_2$  the vector  $\overline{o b}$  parallel and equal to  $\overline{B_1 B_2}$  indicates the displacement of  $B$ .

In like manner the displacement of any number of points may be represented by vectors drawn from the same

FIG. 3.



origin  $o$ . This system of vectors is called the Diagram of Displacement. It is not necessary to draw actual lines to represent these vectors; it is sufficient to indicate the points  $a, b, \&c.$ , at the extremities of the vectors. The diagram of displacement may therefore be regarded as consisting of a number of points,  $a, b, \&c.$ , corresponding with the material particles,  $A, B, \&c.$ , belonging to the system, together with a point  $o$ , the position of which is arbitrary, and which is the assumed origin of all the vectors.

**RELATIVE DISPLACEMENT.**—The line  $\overline{a b}$  in the diagram of displacement represents the displacement of the point  $B$  with respect to  $A$ .

For if in the diagram of displacement (Fig. 3) we draw  $\overline{a k}$  parallel and equal to  $\overline{B_1 A_1}$ , and in the same direction, and join  $\overline{k b}$ , it is easy to show that  $\overline{k b}$  is equal and parallel to  $\overline{A_2 B_2}$ .

For the vector  $\overline{k b}$  is the sum of the vectors  $\overline{k a}$ ,  $\overline{a o}$ , and  $\overline{o b}$ , and  $\overline{A_2 B_2}$  is the sum of  $\overline{A_2 A_1}$ ,  $\overline{A_1 B_1}$ , and  $\overline{B_1 B_2}$ . But of these  $\overline{k a}$  is the same as  $\overline{A_1 B_1}$ ,  $\overline{o o}$  is the same as  $\overline{A_2 A_1}$ , and  $\overline{o b}$  is the same as  $\overline{B_1 B_2}$ , and by "Addition of Vectors," the order of summation is indifferent, so that the vector  $\overline{k b}$  is the same, in direction and magnitude, as  $\overline{A_2 B_2}$ . Now  $\overline{k a}$ , or  $\overline{A_1 B_1}$  represents the original position of  $B$  with respect to  $A$ , and  $\overline{k b}$ ,

or  $\overline{A_2 B_2}$  represents the final position of  $B$  with respect to  $A$ . Hence  $\overline{a b}$  represents the displacement of  $B$  with respect to  $A$ , which was to be proved.

In "Definition of Displacement," we purposely omitted to say whether the origin to which the original configuration was referred, and that to which the final configuration is referred, are absolutely the same point, or whether, during the displacement of the system, the origin also is displaced.

We may now, for the sake of argument, suppose that the origin is absolutely fixed, and that the displacements represented by  $\overline{o a}$ ,  $\overline{o b}$ , &c., are the absolute displacements. To pass from this case to that in which the origin is displaced we have only to take  $A$ , one of the movable points, as origin. The absolute displacement of  $A$  being represented by  $\overline{o a}$ , the displacement of  $B$  with respect to  $A$  is represented, as we have seen, by  $\overline{a b}$ , and so on for any other points of the system.

The arrangement of the points  $a, b, \&c.$ , in the diagram of displacement is therefore the same, whether we reckon the displacements with respect to a fixed point or a displaced point; the only difference is that we adopt a different origin of vectors in the diagram of displacements, the rule being that whatever point we take, whether fixed or moving, for the origin of the diagram of configuration, we take the corresponding point as origin in the diagram of displacement. If we wish to indicate the fact that we are entirely ignorant of the absolute displacement in space of any point of the system we may do so by constructing the diagram of displacements as a mere system of points, without indicating in any way which of them we take as the origin.

This diagram of displacements (without an origin) will then represent neither more nor less than all we can ever know about the displacement of the system. It consists simply of a number of points,  $a, b, c, \&c.$ , corresponding to the points  $A, B, C$ , of the material system, and a vector, as  $\overline{a b}$  represents the displacement of  $B$  with respect to  $A$ .

**UNIFORM\* DISPLACEMENT.**—When the

\* When the simultaneous values of a quantity for different bodies or places are equal, the quantity is said to be uniformly distributed in space.

displacements of all points of a material system with respect to an external point are the same in direction and magnitude, the diagram of displacement is reduced to two points—one corresponding to the external point, and the other to each and every point of the displaced system. In this case the points of the system are not displaced with respect to one another, but only with respect to the external point.

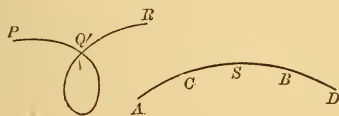
This is the kind of displacement which occurs when a body of invariable form moves parallel to itself. It may be called uniform displacement.

**ON MOTION.**—When the change of configuration of a system is considered with respect only to its state at the beginning and the end of the process of change, and without reference to the time during which it takes place, it is called the displacement of the system.

When we turn our attention to the process of change itself, as taking place during a certain time and in a continuous manner, the change of configuration is ascribed to the motion of the system.

**ON THE CONTINUITY OF MOTION.**—When a material particle is displaced so as to pass from one position to another, it can only do so by traveling along some course or path from the one position to the other.

FIG. 4.



At any instant during the motion the particle will be found at some one point of the path, and if we select any point of the path, the particle will pass that point once at least\* during its motion.

This is what is meant by saying that the particle described a continuous path.

The motion of a material particle which has continuous existence in time and space is the type and exemplar of every form of continuity.

\* If the path cuts itself so as to form a loop, as P, Q, R, (fig. 4), the particle will pass the point of intersection, Q, twice, and if the particle returns on its own path, as in the path A, B, C, D, it may pass the same point, S, three or more times.

**ON CONSTANT\* VELOCITY.**—If the motion of a particle is such that in equal intervals of time, however short, the displacements of the particle are equal and in the same direction, the particle is said to move with constant velocity.

It is manifest that in this case the path of the body will be a straight line, and the length of any part of the path will be proportional to the time of describing it.

The rate or speed of the motion is called the velocity of the particle, and its magnitude is expressed by saying that it is such a distance in such a time, as, for instance, ten miles an hour, or one meter per second. In general we select a unit of time, such as a second and measure velocity by the distance described in unit of time.

If one meter be described in a second and if the velocity be constant, a thousandth or a millionth of a meter will be described in a thousandth or a millionth of a second. Hence, if we can observe or calculate the displacement during any interval of time, however short, we may deduce the distance which would be described in a longer time with the same velocity. This result, which enables us to state the velocity during the short interval of time, does not depend on the body's actually continuing to move at the same rate during the longer time. Thus we may know that a body is moving at the rate of ten miles an hour, though its motion at this rate may last for only the hundredth of a second.

**ON THE MEASUREMENT OF VELOCITY WHEN VARIABLE.**—When the velocity of a particle is not constant, its value at any given instant is measured by the distance which would be described in unit of time by a body having the same velocity as that which the particle has at that instant.

Thus when we say that at a given instant, say one second after a body has begun to fall, its velocity is 980' centimeters per second, we mean that if the velocity of a particle were constant and equal to that of the falling body at the given instant, it would describe 980 centimeters in a second.

It is specially important to understand

\* When the successive values of a quantity for successive instances of time are equal, the quantity is said to be constant.

what is meant by the velocity or rate of motion of a body, because the ideas which are suggested to our minds by considering the motion of a particle are those which Newton made use of in his method of Fluxions,\* and they lie at the foundation of the great extension of exact science which has taken place in modern times.

**DIAGRAM OF VELOCITIES.**—If the velocity of each of the bodies in the system is constant, and if we compare the configurations of the system at an interval of a unit of time, then the displacements, being those produced in unit of time in bodies moving with constant velocities, will represent those velocities according to the method of measurement described "On Constant Velocity."

If the velocities do not actually continue constant for a unit of time, then we must imagine another system consisting of the same number of bodies, and in which the velocities are the same as those of the corresponding bodies of the system at the given instant, but remain constant for a unit of time. The displacements of this system represent the velocities of the actual system at the given instant.

Another mode of obtaining the diagram of velocities of a system at a given instant is to take a small interval of time, say the  $n$ th part of the unit of time, so that the middle of this interval corresponds to the given instant. Take the diagram of displacements corresponding to this interval and magnify all its dimensions  $n$  times. The result will be a diagram of the *mean* velocities of the system during the interval. If we now suppose the number  $n$  to increase without limit the interval will diminish without limit, and the mean velocities will approximate without limit to the actual velocities at the given instant. Finally, when  $n$  becomes infinite the diagram will represent accurately the velocities at the given instant.

**PROPERTIES OF THE DIAGRAM OF VELOCITIES.** (Fig. 5).—The diagram of velocities for a system consisting of a

\* According to the method of Fluxions, when the value of one quantity depends on that of another, the rate of variation of the first quantity with respect to the second may be expressed as a velocity, by imagining the first quantity to represent the displacement of a particle, while the second flows uniformly with the time.

number of material particles consists of a number of points, each corresponding to one of the particles.

FIG. 5.  
A. B.  
C. D.  
DIAGRAM OF  
CONFIGURATION.

b.  
a. c.  
o. d.  
DIAGRAM OF  
VELOCITY.

The velocity of any particle B with respect to any other, A, is represented in direction and magnitude by the line  $\overline{ab}$  in the diagram of velocities, drawn from the point  $a$ , corresponding to A, to the point  $b$ , corresponding to B.

We may in this way find, by means of the diagram, the relative velocity of any two particles. The diagram tells us nothing about the absolute velocity of any point; it expresses exactly what we can know about the motion and no more. If we choose to imagine that  $\overline{oa}$  represents the absolute velocity of A, then the absolute velocity of any other particle, B, will be represented by the vector  $\overline{ob}$ , drawn from  $o$  as origin, to the point  $b$ , which corresponds to B.

But as it is impossible to define the position of a body except with respect to the position of some point of reference, so it is impossible to define the velocity of a body, except with respect to the velocity of the point of reference. The phrase absolute velocity has as little meaning as absolute position. It is better, therefore, not to distinguish any point in the diagram of velocity as the origin, but to regard the diagram as expressing the relations of all the velocities without defining the absolute value of any one of them.

#### MEANING OF THE PHRASE "AT REST."

—It is true that when we say that a body is at rest we use a form of words which appears to assert something about that body considered in itself, and we might imagine that the velocity of another body, if reckoned with respect to a body at rest, would be its true and only absolute velocity. But the phrase

"at rest" means in ordinary language "having no velocity with respect to that on which the body stands," as, for instance, the surface of the earth or the deck of a ship. It cannot be made to mean more than this.

It is therefore unscientific to distinguish between rest and motion, as between two different states of a body in itself, since it is impossible to speak of a body being at rest or in motion except with reference, expressed or implied, to some other body.

ON CHANGE OF VELOCITY.—As we have compared the velocities of different bodies at the same time, so we may compare the relative velocity of one body with respect to another at different times.

If  $a, b, c,$  be the diagram of the velocities of the system of bodies, A, B, C, in

FIG. 6.



its original state, and if  $a_2, b_2, c_2,$  be the diagram of velocities in the final state of the system, then if we take any point  $\omega$  as origin and draw  $\omega \alpha$  equal and parallel to  $a_1 a_2$ ,  $\omega \beta$  equal and parallel to  $b_1 b_2$ ,  $\omega \gamma$  equal and parallel to  $c_1 c_2$ , and so on, we shall form a diagram of points  $\alpha, \beta, \gamma,$  &c., such that any line  $\alpha \beta$  in this diagram represents in direction and magnitude the change of the velocity of B with respect to A. This diagram may be called the diagram of Total Accelerations.

ON ACCELERATION.—The word Acceleration is here used to denote any change in the velocity, whether that change be an increase, a diminution, or a change of direction. Hence, instead of distinguishing, as in ordinary language, between the acceleration, the retardation,

and the deflection of the motion of a body, we say that the acceleration may be in the direction of motion, in the contrary direction, or transverse to that direction.

As the displacement of a system is defined to be the change of the configuration of the system, so the Total Acceleration of the system is defined to be the change of the velocities of the system. The process of constructing the diagram of total accelerations, by a comparison of the initial and final diagrams of velocities, is the same as that by which the diagram of displacements was constructed by a comparison of the initial and final diagrams of configuration.

ON THE RATE OF ACCELERATION.—We have hitherto been considering the total acceleration which takes place during a certain interval of time. If the rate of acceleration is constant, it is measured by the total acceleration in a unit of time. If the rate of acceleration is variable, its value at a given instant is measured by the total acceleration in unit of time of a point whose acceleration is constant and equal to that of the particle at the given instant.

It appears from this definition that the method of deducing the rate of acceleration from a knowledge of the total acceleration in any given time is precisely analogous to that by which the velocity at any instant is deduced from a knowledge of the displacement in any given time.

The diagram of total accelerations constructed for an interval of the  $n$ th part of the unit of time, and then magnified  $n$  times, is a diagram of the mean rates of acceleration during that interval, and by taking the interval smaller and smaller, we ultimately arrive at the true rate of acceleration at the middle of that interval.

As rates of acceleration have to be considered in physical science much more frequently than total accelerations, the word acceleration has come to be employed in the sense in which we have hitherto used the phrase—rate of acceleration.

In future, therefore, when we use the word acceleration without qualification, we mean what we have here described as the rate of acceleration.

**DIAGRAM OF ACCELERATIONS.**—The diagram of accelerations is a system of points, each of which corresponds to one of the bodies of the material system, and is such that any line  $\overline{a\beta}$  in the diagram represents the rate of acceleration of the body B with respect to the body A.

It may be well to observe here that in the diagram of configuration we use the capital letters, A, B, C, &c., to indicate the relative position of the bodies of the system; in the diagram of velocities we use the small letters,  $a, b, c$ , to indicate the relative velocities of these bodies; and in the diagram of accelerations we use the Greek letters,  $\alpha, \beta, \gamma$ , to indicate their relative accelerations.

**ACCELERATION A RELATIVE TERM.**—Acceleration, like position and velocity, is a relative term and cannot be interpreted absolutely.

If every particle of the material universe within the reach of our means of observation were at a given instant to have its velocity altered by compounding therewith a new velocity, the same in magnitude and direction for every such particle, all the relative motions of bodies within the system would go on in a perfectly continuous manner, and neither astronomers nor physicists, though using their instruments all the while, would be able to find out that anything had happened.

It is only if the change of motion occurs in a different manner in the different bodies of the system that any event capable of being observed takes place.

### CHAPTER III.

#### ON FORCE.

**KINEMATICS AND KINETICS.**—We have hitherto been considering the motion of a system in its purely geometrical aspect. We have shown how to study and describe the motion of such a system, however arbitrary, without taking into account any of the conditions of motion which arise from the mutual action between the bodies.

The theory of motion treated in this way is called Kinematics. When the mutual action between bodies is taken into account, the science of motion is called Kinetics, and when special attention is paid to force as the cause of motion, it is called Dynamics.

**MUTUAL ACTION BETWEEN TWO BODIES —STRESS.**—The mutual action between two portions of matter receives different names according to the aspect under which it is studied, and this aspect depends on the extent of the material system which forms the subject of our attention.

If we take into account the whole phenomenon of the action between the two portions of matter, we call it Stress. This stress, according to the mode in which it acts, may be described as Attraction, Repulsion, Tension, Pressure, Shearing stress, Torsion, &c.

**EXTERNAL FORCE.**—But if, as in "Definition of a Material System," we confine our attention to one of the portions of matter, we see, as it were, only one side of the transaction—namely, that which affects the portion of matter under our consideration—and we call this aspect of the phenomenon, with reference to its effect, an External Force acting on that portion of matter, and with reference to its cause we call the Action of the other portion of matter. The opposite aspect of the stress is called the Reaction on the other portion of matter.

**DIFFERENT ASPECTS OF THE SAME PHENOMENON.**—In commercial affairs the same transaction between two parties is called Buying when we consider one party, Selling when we consider the other, and Trade when we take both parties into consideration.

The accountant who examines the records of the transaction finds that the two parties have entered it on opposite sides of their respective ledgers, and in comparing the books he must in every case bear in mind in whose interest each book is made up.

For similar reasons in dynamical investigations we must always remember which of the two bodies we are dealing with, so that we may state the forces in the interest of that body, and not set down any of the forces on the wrong side of the account.

**NEWTON'S LAWS OF MOTION.**—External or "impressed" force considered with reference to its effect—namely, the alteration of the motions of bodies—is completely defined and described in Newton's three laws of motion.

The first law tells us under what conditions there is no external force.

The second shows us how to measure the force when it exists.

The third compares the two aspects of the action between two bodies, as it affects the one body or the other.

THE FIRST LAW OF MOTION.—Law I. *Every body perseveres in its state of rest or of moving uniformly in a straight line, except in so far as it is made to change that state by external forces.*

The experimental argument for the truth of this law is, that in every case in which we find an alteration of the state of motion of a body, we can trace this alteration to some action between that body and another, that is to say, to an external force. The existence of this action is indicated by its effects on the other body when the motion of that body can be observed. Thus the motion of a cannon ball is retarded, but this arises from an action between the projectile and the air which surrounds it, whereby the ball experiences a force in the direction opposite to its relative motion, while the air, pushed forward by an equal force, is itself set in motion, and constitutes what is called the *wind* of the cannon ball.

But our conviction of the truth of this law may be greatly strengthened by considering what is involved in a denial of it. Given a body in motion. At a given instant let it be left to itself and not acted on by any force. What will happen? According to Newton's law it will persevere in moving uniformly in a straight line, that is, its velocity will remain constant both in direction and magnitude.

If the velocity does not remain constant let us suppose it to vary. The change of velocity, as we saw "On Change of Velocity," must have a definite direction and magnitude. By the "Statement of the General Maxim of Physical Science," this variation must be the same whatever be the time or place of the experiment. The direction of the change of motion must therefore be determined either by the direction of the motion itself, or by some direction fixed in the body.

Let us, in the first place, suppose the law to be that the velocity diminishes at a certain rate, which for the sake of the

argument we may suppose so slow that by no experiments on moving bodies could we have detected the diminution of velocity in hundreds of years.

The velocity referred to in this hypothetical law can only be the velocity referred to a point absolutely at rest. For if it is a relative velocity its direction as well as its magnitude depends on the velocity of the point of reference.

If, when referred to a certain point, the body appears to be moving northward with diminishing velocity, we have only to refer it to another point moving northward with a uniform velocity greater than that of the body, and it will appear to be moving southward with increasing velocity.

Hence the hypothetical law is without meaning, unless we admit the possibility of defining absolute rest and absolute velocity.

Even if we admit this as a possibility, the hypothetical law, if found to be true, might be interpreted, not as a contradiction of Newton's law, but as evidence of the resisting action of some medium in space.

To take another case. Suppose the law to be that a body, not acted on by any force, ceases at once to move. This is not only contradicted by experience, but it leads to a definition of absolute rest as the state which a body assumes as soon as it is freed from the action of external forces.

It may thus be shown that the denial of Newton's law is in contradiction to the only system of consistent doctrine about space and time which the human mind has been able to form.

ON THE EQUILIBRIUM OF FORCES.—If a body moves with constant velocity in a straight line, the external forces, if any, which act on it, balance each other, or are in equilibrium.

Thus if a carriage in a railway train moves with constant velocity in a straight line, the external forces which act on it—such as the traction of the carriage in front of it pulling it forwards, the drag of that behind it, the friction of the rails, the resistance of the air acting backwards, the weight of the carriage acting downwards, and the pressure of the rails acting upwards—must exactly balance each other.

Bodies at rest with respect to the surface of the earth are really in motion, and their motion is not constant nor in a straight line. Hence the forces which act on them are not exactly balanced. The apparent weight of bodies is estimated by the upward force required to keep them at rest relatively to the earth. The apparent weight is therefore rather less than the attraction of the earth, and makes a smaller angle with the axis of the earth, so that the combined effect of the supporting force and the earth's attraction is a force perpendicular to the earth's axis just sufficient to cause the body to keep to the circular path which it must describe if resting on the earth.

**DEFINITION OF EQUAL TIMES.**—The first law of motion, by stating under what circumstances the velocity of a moving body remains constant, supplies us with a method of defining equal intervals of time. Let the material system consist of two bodies which do not act on one another, and which are not acted on by any body external to the system. If one of these bodies is in motion with respect to the other, the relative velocity will, by the first law of motion, be constant and in a straight line.

Hence intervals of time are equal when the relative displacements during those intervals are equal.

This might at first sight appear to be nothing more than a definition of what we mean by equal intervals of time, an expression which we have not hitherto defined at all.

But if we suppose another moving system of two bodies to exist, each of which is not acted upon by any body whatever, this second system will give us an independent method of comparing intervals of time.

The statement that equal intervals of time are those during which equal displacements occur in any such system, is therefore equivalent to the assertion that the comparison of intervals of time leads to the same result, whether we use the first system of two bodies or the second system as our time-piece.

We thus see the theoretical possibility of comparing intervals of time however distant, though it is hardly necessary to remark that the method cannot be put in practice in the neighborhood of the

earth, or any other large mass of gravitating matter.

**THE SECOND LAW OF MOTION.**—Law II.—*Change of motion is proportional to the impressed force, and takes place in the direction in which the force is impressed.*

By motion Newton means what in modern scientific language is called momentum, in which the quantity of matter moved is taken into account as well as the rate at which it travels.

By impressed force he means what is now called Impulse, in which the time during which the force acts is taken into account as well as the intensity of the force.

**DEFINITION OF EQUAL MASSES AND OF EQUAL FORCES.**—An exposition of the law therefore involves a definition of equal quantities of matter and of equal forces.

We shall assume that it is possible to cause the force with which one body acts on another to be of the same intensity on different occasions.

If we admit the permanency of the properties of bodies this can be done. We know that a thread of caoutchouc when stretched beyond a certain length exerts a tension which increases the more the thread is elongated. On account of this property the thread is said to be elastic. When the same thread is drawn out to the same length it will, if its properties remain constant, exert the same tension. Now let one end of the thread be fastened to a body, M, not acted on by any other force than the tension of the thread, and let the other end be held in the hand and pulled in a constant direction with a force just sufficient to elongate the thread to a given length; the force acting on the body will then be of a given intensity, F. The body will acquire velocity, and at the end of a unit of time this velocity will have a certain value, V.

If the same string be fastened to another body, N, and pulled as in the former case, so that the elongation is the same as before, the force acting on the body will be the same, and if the velocity communicated to N in a unit of time is also the same, namely, V, then we say of the two bodies M and N that they consist of equal quantities of mat-

ter, or, in modern language, they are equal in mass. In this way, by the use of an elastic string, we might adjust the masses of a number of bodies so as to be each equal to a standard unit of mass, such as a pound avoirdupois, which is the standard of mass in Britain.

**MEASUREMENT OF MASS.**—The scientific value of the dynamical method of comparing quantities of matter is best seen by comparing it with other methods in actual use.

As long as we have to do with bodies of exactly the same kind, there is no difficulty in understanding how the quantity of matter is to be measured. If equal quantities of the substance produce equal effects of any kind, we may employ these effects as measures of the quantity of the substance.

For instance, if we are dealing with sulphuric acid of uniform strength, we may estimate the quantity of a given portion of it in several different ways. We may weigh it, we may pour it into a graduated vessel, and so measure its volume, or we may ascertain how much of a standard solution of potash it will neutralize.

We might use the same methods to estimate a quantity of nitric acid if we were dealing only with nitric acid; but if we wished to compare a quantity of nitric acid with a quantity of sulphuric acid we should obtain different results by weighing, by measuring, and by testing with an alkaline solution.

Of these three methods, that of weighing depends on the attraction between the acid and the earth, that of measuring depends on the volume which the acid occupies, and that of titration depends on its power of combining with potash.

In abstract dynamics, however, matter is considered under no other aspect than as that which can have its motion changed by the application of force. Hence any two bodies are of equal mass if equal forces applied to these bodies produce, in equal times, equal changes of velocity. This is the only definition of equal masses which can be admitted in dynamics, and it is applicable to all material bodies, whatever they may be made of.

It is an observed fact that bodies of equal mass, placed in the same position relative to the earth, are attracted equally

towards the earth, whatever they are made of; but this is not a doctrine of abstract dynamics, founded on axiomatic principles, but a fact discovered by observation, and verified by the careful experiments of Newton,\* on the times of oscillation of hollow wooden balls suspended by strings of the same length, and containing gold, silver, lead, glass, sand, common salt, wood, water, and wheat.

The fact, however, that in the same geographical position the weights of equal masses are equal, is so well established, that no other mode of comparing masses than that of comparing their weights is ever made use of, either in commerce or in science, except in researches undertaken for the special purpose of determining, in absolute measure, the weight of unit of mass at different parts of the earth's surface. The method employed in these researches is essentially the same as that of Newton, namely, by measuring the length of a pendulum which swings seconds.

The unit of mass in this country is defined by the Act of Parliament (18 & 19 Vict. c. 72, July 30, 1855) to be a piece of platinum marked "P. S., 1844, 1 lb." deposited in the office of the Exchequer, which "shall be and be denominated the Imperial Standard Pound Avoirdupois." One seven-thousandth part of this pound is a grain. The French Standard of mass is the "Kilogramme des Archives," made of platinum by Borda. Professor Miller finds the kilogramme equal to 15432.34874 grains.

#### NUMERICAL MEASUREMENT OF FORCE.

—The unit of force is that force which, acting on the unit of mass for the unit of time, generates unit of velocity.

Thus the weight of a gramme—that is to say, the force which causes it to fall—may be asserted by letting it fall freely. At the end of one second its velocity will be about 981 centimeters per second if the experiment be in Britain. Hence the weight of a gramme is represented by the number 981, if the centimeter, the gramme, and the second are taken as the fundamental units.

It is sometimes convenient to compare forces with the weight of a body, and to speak of a force of so many pounds

\* "Principia," III., Prop. 6.

weight or grammes weight. This is called Gravitation measure. We must remember, however, that though a pound or a gramme is the same all over the world, the weight of a pound or a gramme is greater in high latitudes than near the equator, and therefore a measurement of force in gravitation measure is of no scientific value unless it is stated in what part of the world the measurement was made.

If, as in Britain, the units of length, mass, and time are one foot, one pound, and one second, the unit of force is that which, in one second, would communicate to one pound a velocity of one foot per second. This unit of force is called a *Poundal*.

In the French metric system the units are one centimeter, one gramme, and one second. The force which in one second would communicate to one gramme a velocity of one centimeter per second is called a *Dyne*.

Since the foot is 30.4797 centimeters and the pound is 453.59 grammes, the poundal is 13825.38 dynes.

**SIMULTANEOUS ACTION OF FORCES ON A BODY.**—Now let a unit of force act for unit of time upon unit of mass. The velocity of the mass will be changed, and the total acceleration will be unity in the direction of the force.

The magnitude and direction of this total acceleration will be the same whether the body is originally at rest or in motion. For the expression "at rest" has no scientific meaning, and the expression "in motion," if it refers to relative motion, may mean anything, and if it refers to absolute motion can only refer to some medium fixed in space. To discover the existence of a medium, and to determine our velocity with respect to it by observation on the motion of bodies, is a legitimate scientific inquiry, but supposing all this done we should have discovered, not an error in the laws of motion, but a new fact in science.

Hence the effect of a given force on a body does not depend on the motion of that body.

Neither is it affected by the simultaneous action of other forces on the body. For the effect of these forces on the body is only to produce motion in the

body, and this does not affect the acceleration produced by the first force.

Hence we arrive at the following form of the law. *When any number of forces act on a body, the acceleration due to each force is the same in direction and magnitude as if the others had not been in action.*

When a force, constant in direction and magnitude, acts on a body, the total acceleration is proportional to the interval of time during which the force acts.

For if the force produces a certain total acceleration in a given interval of time, it will produce an equal total acceleration in the next, because the effect of the force does not depend upon the velocity which the body has when the force acts on it. Hence in every equal interval of time there will be an equal change of the velocity, and the total change of velocity from the beginning of the motion will be proportional to the time of action of the force.

The total acceleration in a given time is proportional to the force.

For if several equal forces act in the same direction on the same body in the same direction, each produces its effect independently of the others. Hence the total acceleration is proportional to the number of the equal forces.

**ON IMPULSE.**—The total effect of a force in communicating velocity to a body is therefore proportional to the force and to the time during which it acts conjointly.

The product of the time of action of a force into its intensity if it is constant, or its mean intensity if it is variable, is called the *Impulse* of the force.

There are certain cases in which a force acts for so short a time that it is difficult to estimate either its intensity or the time during which it acts. But it is comparatively easy to measure the effect of the force in altering the motion of the body on which it acts, which, as we have seen, depends on the impulse.

The word impulse was originally used to denote the effect of a force of short duration, such as that of a hammer striking a nail. There is no essential difference, however, between this case and any other case of the action of force. We shall therefore use the word impulse as above defined, without restricting it

to cases in which the action is of an exceptionally transient character.

#### RELATION BETWEEN FORCE AND MASS.

—If a force acts on a unit of mass for a certain interval of time, the impulse, as we have seen, is measured by the velocity generated.

If a number of equal forces act in the same direction, each on a unit of mass, the different masses will all move in the same manner, and may be joined together into one body without altering the phenomenon. The velocity of the whole body is equal to that produced by one of the forces acting on a unit of mass.

Hence the force required to produce a given change of velocity in a given time is proportional to the number of units of mass of which the body consists.

ON MOMENTUM.—The numerical value of the Momentum of a body is the product of the number of units of mass in the body into the number of units of velocity with which it is moving.

The momentum of any body is thus measured in terms of the momentum of unit of mass moving with unit of velocity, which is taken as the unit of momentum.

The direction of the momentum is the same as that of the velocity, and as the velocity can only be estimated with respect to some point of reference, so the particular value of the momentum depends on the point of reference which we assume. The momentum of the moon, for example, will be very different according as we take the earth or the sun for the point of reference.

STATEMENT OF THE SECOND LAW OF MOTION IN TERMS OF IMPULSE AND MOMENTUM.—*The change of momentum of a body is numerically equal to the impulse which produces it, and is in the same direction.*

ADDITION OF FORCES.—If any number of forces act simultaneously on a body, each force produces an acceleration proportional to its own magnitude ("Measurement of Mass"). Hence if in the diagram of accelerations (See "Diagram of Accelerations") we draw from any origin a line representing in direction and magnitude the acceleration due to one of the

forces, and from the end of this line another representing the acceleration due to another force, and so on, drawing lines for each of the forces taken in any order, then the line drawn from the origin to the extremity of the last of the lines will represent the acceleration due to the combined action of all the forces.

Since in this diagram lines which represent the accelerations are in the same proportion as the forces to which these accelerations are due, we may consider the lines as representing these forces themselves. The diagram, thus understood, may be called a Diagram of Forces, and the line from the origin to the extremity of the series represents the Resultant Force.

An important case is that in which the set of lines representing the forces terminate at the origin so as to form a closed figure. In this case there is no resultant force, and no acceleration. The effects of the forces are exactly balanced, and the case is one of equilibrium. The discussion of cases of equilibrium forms the subject of the science of Statics.

It is manifest that since the system of forces is exactly balanced, and is equivalent to no force at all, the forces will also be balanced if they act in the same way on any other material system, whatever be the mass of that system. This is the reason why the consideration of mass does not enter into statical investigations.

THE THIRD LAW OF MOTION.—Law III.—*Reaction is always equal and opposite to action, that is to say, the actions of two bodies upon each other are always equal and in opposite directions.*

When the bodies between which the action takes place are not acted on by any other force, the changes in their respective momenta produced by the action are equal and in opposite directions.

The changes in the velocities of the two bodies are also in opposite directions, but not equal, except in the case of equal masses. In other cases the changes of velocity are in the inverse ratio of the masses.

ACTION AND REACTION ARE THE PARTIAL ASPECTS OF A STRESS.—We have already ("Mutual Action—Stress," etc.) used the word stress to denote the mutual action between two portions of matter.

This word was borrowed from common language, and invested with a precise scientific meaning by the late Professor Rankine, to whom we are indebted for several other valuable scientific terms.

As soon as we have formed for ourselves the idea of a stress, such as the Tension of a rope or the Pressure between two bodies, and have recognized its double aspect as it affects the two portions of matter between which it acts, the third law of motion is seen to be equivalent to the statement that all force is of the nature of stress, that stress exists only between two portions of matter, and that its effects on these portions of matter (measured by the momentum generated in a given time) are equal and opposite.

The stress is measured numerically by the force exerted on either of the two portions of matter. It is distinguished as a tension when the force acting on either portion is towards the other, and as a pressure when the force acting on either portion is away from the other.

When the force is inclined to the surface which separates the two portions of matter the stress cannot be distinguished by any term in ordinary language, but must be defined by technical mathematical terms.

When a tension is exerted between two bodies by the medium of a string, the stress, properly speaking, is between any two parts into which the string may be supposed to be divided by an imaginary section or transverse interface. If, however, we neglect the weight of the string, each portion of the string is in equilibrium under the action of the tensions at its extremities, so that the tensions at any two transverse interfaces of the string must be the same. For this reason we often speak of the tension of the string as a whole, without specifying any particular section of it, and also the tension between the two bodies, without considering the nature of the string through which the tension is exerted.

**ATTRACTION AND REPULSION.**—There are other cases in which two bodies at a distance appear mutually to act on each other, though we are not able to detect any intermediate body, like the string in the former example, through which the action takes place. For instance,

two magnets or two electrified bodies appear to act on each other when placed at considerable distances apart, and the motions of the heavenly bodies are observed to be affected in a manner which depends on their relative position.

This mutual action between distant bodies is called attraction when it tends to bring them nearer, and repulsion when it tends to separate them.

In all cases, however, the action and reaction between the bodies are equal and opposite.

**THE THIRD LAW TRUE OF ACTION AT A DISTANCE.**—The fact that a magnet draws iron towards it was noticed by the ancients, but no attention was paid to the force with which the iron attracts the magnet. Newton, however, by placing the magnet in one vessel and the iron in another, and floating both vessels in water so as to touch each other, showed experimentally that as neither vessel was able to propel the other along with itself through the water, the attraction of the iron on the magnet must be equal and opposite to that of the magnet on the iron, both being equal to the pressure between the two vessels.

Having given this experimental illustration Newton goes on to point out the consequence of denying the truth of this law. For instance, if the attraction of any part of the earth, say a mountain, upon the remainder of the earth were greater or less than that of the remainder of the earth upon the mountain, there would be a residual force, acting upon the system of the earth and the mountain as a whole, which would cause it to move off, with an ever-increasing velocity, through infinite space.

**NEWTON'S PROOF NOT EXPERIMENTAL.**—This is contrary to the first law of motion, which asserts that a body does not change its state of motion unless acted on by *external* force. It cannot be affirmed to be contrary to experience, for the effect of an inequality between the attraction of the earth on the mountain and the mountain on the earth would be the same as that of a force equal to the difference of these attractions acting in the direction of the line joining the center of the earth with the mountain.

If the mountain were at the equator the earth would be made to rotate about

an axis parallel to the axis about which it would otherwise rotate, but not passing exactly through the center of the earth's mass.

If the mountain were at one of the poles, the constant force parallel to the earth's axis would cause the orbit of the earth about the sun to be slightly shifted to the north or south of a plane passing through the center of the sun's mass.

If the mountain were at any other part of the earth's surface its effect would be partly of the one kind and partly of the other.

Neither of these effects, unless they were very large, could be detected by direct astronomical observations, and the indirect method of detecting small forces, by their effect in slowly altering the elements of a planet's orbit, presupposes that the law of gravitation is known to be true. To prove the laws of motion by the law of gravitation would be an inversion of scientific order. We might as well prove the law of addition of numbers by the differential calculus.

We cannot, therefore, regard Newton's statement as an appeal to experience and observation, but rather as a deduction of the third law of motion from the first.

#### CHAPTER IV.

##### ON THE PROPERTIES OF THE CENTER OF MASS OF A MATERIAL SYSTEM.

**DEFINITION OF A MASS-VECTOR.**—We have seen that a vector represents the operation of carrying a tracing point from a given origin to a given point.

Let us define a mass-vector as the operation of carrying a given mass from the origin to the given point. The direction of the mass-vector is the same as that of the vector of the mass, but its magnitude is the product of the mass into the vector of the mass.

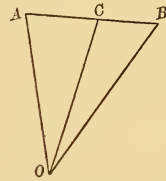
Thus if  $\overline{OA}$  is the vector of the mass  $A$ , the mass-vector is  $\overline{OA.A}$ .

**CENTER OF MASS OF TWO PARTICLES.**—If  $A$  and  $B$  are two masses, and if a point  $C$  be taken in the straight line  $AB$ , so that  $\overline{BC}$  is to  $\overline{CA}$  as  $A$  to  $B$ , then the mass-vector of a mass  $A+B$  placed at  $C$  is equal to the sum of the mass-vectors of  $A$  and  $B$ . —

$$\begin{aligned}\text{For } \overline{OA.A} + \overline{OB.B} &= (\overline{OC} + \overline{CA})A + (\overline{OC} \\ &\quad + \overline{CB})B. \\ &= \overline{OC}(A+B) + \overline{CA.A} \\ &\quad + \overline{CB.B}.\end{aligned}$$

Now the mass-vectors  $\overline{CA.A}$  and  $\overline{CB.B}$  are equal and opposite, and so destroy each other, so that  $\overline{OA.A} + \overline{OB.B} = \overline{OC}(A+B)$

FIG. 7.



or,  $C$  is a point such that if the masses of  $A$  and  $B$  were concentrated at  $C$ , their mass-vector from any origin  $O$  would be the same as when  $A$  and  $B$  are in their actual positions. The point  $C$  is called the *Center of Mass* of  $A$  and  $B$ .

**CENTER OF MASS OF A SYSTEM.**—If the system consists of any number of particles, we may begin by finding the center of mass of any two particles, and substituting for the two particles a particle equal to their sum placed at their center of mass. We may then find the center of mass of this particle, together with the third particle of the system, and place the sum of the three particles at this point, and so on till we have found the center of mass of the whole system.

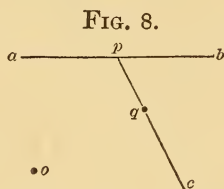
The mass-vector drawn from any origin to a mass, equal to that of the whole system placed at the center of mass of the system, is equal to the sum of the mass-vectors drawn from the same origin to all the particles of the system.

It follows, from the proof in "Center of Mass of Two Particles," that the point found by the construction here given satisfies this condition. It is plain from the condition itself that only one point can satisfy it. Hence the construction must lead to the same result, as to the position of the center of mass, in whatever order we take the particles of the system.

The center of mass is therefore a definite point in the diagram of the configuration of the system. By assigning to

the different points in the diagrams of displacement, velocity, total acceleration, and rate of acceleration, the masses of the bodies to which they correspond, we may find in each of these diagrams a point which corresponds to the center of mass, and indicates the displacement, velocity, total acceleration of the center of mass.

**MOMENTUM, REPRESENTED AS THE RATE OF CHANGE OF A MASS-VECTOR.**—In the diagram of velocities, if the points  $o, a, b, c$ , correspond to the velocities of the origin  $O$  and the bodies  $A, B, C$ , and if  $p$  be the center of mass of  $A$  and  $B$  placed at  $a$  and  $b$  respectively, and if  $q$  is the center of mass of  $A+B$  placed at  $p$  and  $C$  at  $c$ , then  $q$  will be the center of mass of the system of bodies  $A, B, C$ , at  $a, b, c$ , respectively.



The velocity of  $A$  with respect to  $O$  is indicated by the vector  $oa$ , and that of  $B$  and  $C$  by  $ob$  and  $oc$ .  $op$  is the velocity of the center of mass of  $A$  and  $B$ , and  $oq$  that of the center of mass of  $A, B$ , and  $C$ , with respect to  $O$ .

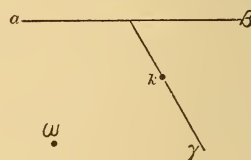
The momentum of  $A$  with respect to  $O$  is the product of the velocity into the mass, or  $oa.A$ , or what we have already called the mass-vector, drawn from  $o$  to the mass  $A$  at  $a$ . Similarly the momentum of any other body is the mass-vector drawn from  $o$  to the point on the diagram of velocities corresponding to that body, and the momentum of the mass of the system concentrated at the center of mass is the mass-vector drawn from  $o$  to the whole mass at  $q$ .

Since, therefore, a mass-vector in the diagram of velocities is what we have already defined as a momentum, we may state the property proved in "Center of Mass of a System," in terms of momenta, thus: The momentum of a mass equal to that of the whole system, moving with the velocity of the center of mass of the system, is equal in magnitude and parallel in direction to the sum of the

momenta of all the particles of the system.

**EFFECT OF EXTERNAL FORCES ON THE MOTION OF THE CENTER OF MASS.**—In the same way in the diagram of Total Acceleration the vectors  $oa, ob$ , drawn from the origin, represent the change of velocity of the bodies  $A, B$ , &c., during a certain interval of time. The corresponding mass-vectors,  $oa.A, ob.B$ , &c., represent the corresponding changes

FIG. 9.



of momentum, or, by the second law of motion, the impulses of the forces acting on these bodies during that interval of time. If  $k$  is the center of mass of the system  $ok$  is the change of velocity during the interval, and  $ok(A+B+C)$  is the momentum generated in the mass concentrated at the center of gravity. Hence, by "Center of Mass of a System," the change of momentum of the imaginary mass equal to that of the whole system concentrated at the center of mass is equal to the sum of the changes of momentum of all the different bodies of the system.

In virtue of the second law of motion we may put this result in the following form:

The effect of the forces acting on the different bodies of the system in altering the motion of the center of mass of the system is the same as if all these forces had been applied to a mass equal to the whole mass of system, and coinciding with its center of mass.

**THE MOTION OF THE CENTER OF MASS OF A SYSTEM IS NOT AFFECTED BY THE MUTUAL ACTION OF THE PARTS OF THE SYSTEM.**—For if there is an action between two parts of the system, say  $A$  and  $B$ , the action of  $A$  on  $B$  is always, by the third law of motion, equal and opposite to the reaction of  $B$  on  $A$ . The momentum generated in  $B$  by the action of  $A$  during any interval is therefore equal and opposite to that generated in

A by the reaction of B during the same interval, and the motion of the center of mass of A and B is therefore not affected by their mutual action.

We may apply the result of the last article to this case and say, that since the forces on A and on B arising from their mutual action are equal and opposite, and since the effect of these forces on the motion of the center of mass of the system is the same as if they had been applied to a particle whose mass is equal to the whole mass of the system, and since the effect of two forces equal and opposite to each other is zero, the motion of the center of mass will not be affected.

#### FIRST AND SECOND LAWS OF MOTION.

—This is a very important result. It enables us to render more precise the enunciation of the first and second laws of motion, by defining that by the velocity of a body is meant the velocity of its center of mass. The body may be rotating, or it may consist of parts, and be capable of changes of configuration, so that the motions of different parts may be different, but we can still assert the laws of motion in the following form :

Law I. The center of mass of the system perseveres in its state of rest, or of uniform motion in a straight line, except in so far as it is made to change that state by forces acting on the system from without.

Law II. The change of momentum of the system during any interval of time is measured by the sum of the impulses of the external forces during that interval.

METHOD OF TREATING SYSTEMS OF MOLECULES.—When the system is made up of parts which are so small that we cannot observe them, and whose motions are so rapid and so variable that even if we could observe them we could not describe them, we are still able to deal with the motion of the center of mass of the system, because the internal forces which cause the variation of the motion of the parts do not affect the motion of the center of mass.

BY THE INTRODUCTION OF THE IDEA OF MASS WE PASS FROM POINT-VECTORS, POINT DISPLACEMENTS, VELOCITIES,

TOTAL ACCELERATIONS, AND RATES OF ACCELERATION, TO MASS-VECTORS, MASS DISPLACEMENTS, MOMENTA, IMPULSES, AND MOVING FORCES.—In the diagram of rates of acceleration (Fig. 9, "Effect of External Forces on the Motion of the Center of Mass"), the vectors  $\vec{\omega a}$ ,  $\vec{\omega \beta}$ , &c., drawn from the origin, represent the rates of acceleration of the bodies A, B, &c., at a given instant, with respect to that of the origin O.

The corresponding mass-vectors,  $\vec{\omega a} \cdot A$ ,  $\vec{\omega \beta} \cdot B$ , &c., represent the forces acting on the bodies A, B, &c.

We sometimes speak of several forces acting on a body, when the force acting on the body arises from several different causes, so that we naturally consider the parts of the force arising from these different causes separately.

But when we consider force, not with respect to its causes, but with respect to its effect—that of altering the motion of a body—we speak not of the forces, but of the force acting on the body, and this force is measured by the rate of change of the momentum of the body, and is indicated by the mass-vector in the diagram of rates of acceleration.

We have thus a series of different kinds of mass-vectors corresponding to the series of vectors which we have already discussed.

We have, in the first place, a system of mass-vectors with a common origin, which we may regard as a method of indicating the distribution of mass in a material system, just as the corresponding system of vectors indicate the geometrical configuration of the system.

In the next place, by comparing the distribution of mass at two different epochs, we obtain a system of mass-vectors of displacement.

The rate of mass displacement is momentum, just as the rate of displacement is velocity.

The change of momentum is impulse as the change of velocity is total acceleration.

The rate of change of momentum is moving force, as the rate of change of velocity is rate of acceleration.

DEFINITION OF A MASS-AREA.—When a material particle moves from one point to another, twice the area swept out by the vector of the particle multi-

plied by the mass of the particle is called the mass-area of the displacement of the particle with respect to the origin from which the vector is drawn.

If the area is in one plane, the direction of the mass-area is normal to the plane, drawn so that, looking in the positive direction along the normal, the motion of the particle round its area appears to be the direction of the motion of the hands of a watch.

If the area is in one plane, the path of the particle must be divided into portions so small that each coincides sensibly with a straight line, and the mass-areas corresponding to these portions must be added together by the rule for the addition of vectors.

**ANGULAR MOMENTUM.**—The rate of change of a mass-area is twice the mass of the particle into the triangle, whose vertex is the origin and whose base is the velocity of the particle measured along the line through the particle in the direction of its motion. The direction of this mass-area is indicated by the normal drawn according to the rule given above.

The rate of change of the mass-area of a particle is called the Angular Momentum of the particle about the origin, and the sum of the angular momenta of all the particles is called the angular momentum of the system about the origin.

The angular momentum of a material system with respect to a point is, therefore, a quantity having a definite direction as well as a definite magnitude.

The definition of the angular momentum of a particle about a point may be expressed somewhat differently—as the product of the momentum of the particle with respect to that point into the perpendicular from that point on the line of motion of the particle at that instant.

**MOMENT OF A FORCE ABOUT A POINT.**—The rate of increase of the angular momentum of a particle is the continued product of the rate of acceleration of the velocity of the particle into the mass of the particle into the perpendicular from the origin on the line through the particle along which the acceleration takes place. In other words, it is the product of the moving force acting on the parti-

cle into the perpendicular from the origin on the line of action of this force.

Now the produce of a force into the perpendicular from the origin on its line of action is called the Moment of the Force about the origin. The axis of the moment, which indicates its direction, is a vector drawn perpendicular to the plane passing through the force and the origin, and in such a direction that looking along this line in the direction in which it is drawn, the force tends to move the particle round the origin in the direction of the hands of a watch.

Hence the rate of change of the angular momentum of a particle about the origin is measured by the moment of the force which acts on the particle about that point.

The rate of change of the angular momentum of a material system about the origin is in like manner measured by the geometric sum of the moments of the forces which act on the particles of the system.

**CONSERVATION OF ANGULAR MOMENTUM.**—Now consider any two particles of the system. The forces acting on these two particles, arising from their mutual action, are equal, opposite, and in the same straight line. Hence the moments of these forces about any point as origin are equal, opposite, and about the same axis. The sum of these moments is therefore zero. In like manner the mutual action between every other pair of particles in the system consists of two forces, the sum of whose moments is zero.

Hence the mutual action between the bodies of a material system does not affect the geometric sum of the moments of the forces. The only forces, therefore, which need be considered in finding the geometric sum of the moments are those which are external to the system—that is to say, between the whole or any part of the system and bodies not included in the system.

The rate of change of the angular momentum of the system is therefore measured by the geometric sum of the moments of the external forces acting on the system.

If the directions of all the external forces pass through the origin, their moments are zero, and the angular mo-

mentum of the system will remain constant.

When a planet describes an orbit about the sun, the direction of the mutual action between the two bodies always passes through their common center of mass. Hence the angular momentum of either body about their common center of mass remains constant, so far as these two bodies only are concerned, though it may be affected by

the action of other planets. If, however, we include all the planets in the system, the geometric sum of their angular momenta about their common center of mass will remain absolutely constant, whatever may be their mutual actions, provided no force arising from bodies external to the whole solar system acts in an unequal manner upon the different members of the system.

## STEEL SHIPS.

From "The Nautical Magazine."

FOR some years past, naval architects have been looking forward to the period when steel would definitely take the place of iron in shipbuilding, and it is now said that we are on the eve of the change. When some years ago steel was talked of, which would take a breaking-strain of over fifty-tons to the square inch, it was thought that ships might be built of half the weight of material required in the case of iron. The strong steel was tried and found to be altogether unreliable, plates with no perceptible fault would suddenly break after they had been riveted up in the ship, and altogether the material was pronounced to be of such uncertain character as to be unfit for shipbuilding. Since that time, however, another kind of steel has been introduced, and now vessels have been built of it for the Admiralty and for the merchant service, and recently the Committee of Lloyd's Register have issued a circular on the subject, giving the general conditions under which it may be used, and the percentage of reduction in the scantlings for iron ships which may be allowed when steel is substituted for iron. It is now said that *mild* steel may be made as reliable as wrought-iron, but the idea of doing with half the weight of material and having a breaking-strain of fifty-tons to the square inch has been abandoned; the steel now used takes a breaking-strain of about twenty-seven tons, and a reduction of twenty per cent. in scantlings is the extent of what is to be allowed for it.

It may, perhaps, be as well for us to

preface our remarks upon the question of steel ships by a few words upon the difference between iron and steel, or rather the metal to which the latter terms has hitherto been applied. In most of the methods in use for extracting iron and steel from the ores, the first part of the process has had for its object the production of pigs of cast-iron. This is only of use for castings; it cannot be welded or otherwise worked, owing to the presence of impurities of which the chief are silicon, sulphur, phosphorus, and carbon. These substances are found in very variable proportions in cast-iron, the last named, however, usually constitutes two to five per cent.

Wrought-iron is mostly obtained from cast-iron by processes having for their object the removal of these substances, the name "wrought-iron" being restricted by metallurgists to the metal capable of being welded and containing less than  $\frac{3}{100}$  per cent. of carbon. Even when there is more than  $\frac{2}{100}$  per cent. of carbon, the metal is spoken of as a "steely" iron. The process by which wrought-iron has usually been produced from cast-iron, is known as "puddling," the pigs are melted in a furnace where they are apart from the fuel, and the fluid mass is exposed to the action of oxygen, partly obtained from the air, partly by having stirred up with it powdered iron ore, rich in oxygen. The temperature of the puddling furnace is so moderated that the iron, as it is freed from its impurities, becomes pasty and then solidifies, the melting point of pure

iron being much higher than that of the alloys which constitute pig-iron. The process of puddling has usually been accomplished by manual labor, and the wrought-iron which is drawn from the furnace in the shape of balls is not of the same character throughout, owing to its having been produced in a pasty condition. The presence of cinder and other imperfections, is also said to cause that want of homogeneity which produces the appearance of "grain" or fibre in wrought iron. The fibre is, of course, drawn out by the subsequent processes of hammering and rolling, by which plates and angle irons are manufactured from the puddled balls. The term *steel* has been applied to an alloy of iron intermediate in character between wrought-iron and cast-iron. In works on metallurgy, it is usually stated that when iron is alloyed with carbon to the extent of over three and under eighteen or twenty parts in the thousand, the metal takes the name of steel. The characteristic properties of steel, however, are, that it is malleable like wrought-iron, and that if it be heated, and then plunged into a cold fluid, it is hardened by such treatment,—in other words it can be *tempered*. The quality of steel is more injuriously affected by the presence of impurities than is that of wrought iron. Thus it is stated, that pure steel, with as much as three per cent. of carbon, is a malleable metal, but Bessemer steel, in which there is present but a very small proportion of silicon, is not malleable when the percentage of carbon exceeds two. For this reason it has been usual to make steel from wrought-iron, the metal being first decarburized and purified, and then a proportion of carbon reintroduced. The best kinds of steel are so made now, and previous to the introduction of the Bessemer process, all steel made in England was made from wrought-iron. In the Bessemer process steel is made directly from pig-iron, which is melted and run into a large heated vessel called a "converter" where a blast of air is passed through it, and the carbon and silicon are thus burnt out. When this is accomplished, a quantity of *spiegeleisen*, a cast-iron which contains a definite percentage of carbon, and which at the same time is free from deleterious mat-

ters, is introduced in a molten state, and the mixed metal is then cast in moulds. A material can thus be produced with any required percentage of carbon. Latterly, a specially prepared alloy, known as ferro-manganese, has been used in place of *spiegeleisen* in the manufacture of some kinds of steel. In another method, known as the Siemens-Martin process, steel is made from pig-iron, *spiegeleisen*, and steel or iron scraps in a special kind of furnace called the "Open Hearth," the distinguishing peculiarity of which is that the flame of coal-gas is made to play upon the metal. This process is much slower than the Bessemer, and was at one time thought to be more exact, it being practicable to take out samples of the metal from time to time, and ascertain its degree of carburization. The metal known as *mild steel*, the employment of which in shipbuilding is the subject of this article, was first manufactured for shipbuilding purposes by the Siemens-Martin method, and it was said that the necessary exactness in composition could not be secured by the Bessemer process, but it is now made in both ways with equally good results. At some steel works both methods are adopted, and we may suppose the cost of production, and the material produced, are the same in each case, from the fact that in one parcel of plates, specimens of both processes are frequently mixed.

If the name *steel* be restricted to metal containing the percentage of carbon mentioned, or to metal capable of being tempered, the so-called "mild steel" is not steel at all, but is really a kind of wrought-iron manufactured by the same process as steel, differing from ordinary wrought-iron by its greater purity, and by being homogeneous, that is by having no *grain*. Instead of being refined in a pasty form, it is refined as a liquid and cast in ingots, and the names "ingot iron" and "homogeneous iron" have both been proposed for it, but it has received the name of "mild steel," and appears likely to keep it. The proportion of carbon in *mild steel* is said to be generally less than  $\frac{1}{10}$  per cent., and very rarely as much as  $\frac{2}{10}$  per cent., while puddled wrought-iron frequently contains  $\frac{2}{10}$  per cent. of carbon. Some manufacturers attribute the peculiar qualities of the metal to the presence of

manganese; others say that although manganese is most useful in the progress of manufacture, it is often almost absent in the finished metal, and when present is of no benefit to it. There is, however, so much diversity of opinion, that all that can be said with certainty is that a metal has been produced in large quantities by modifications of methods used to manufacture steel, that this metal is homogeneous, being equally strong in every direction, and that it has a higher breaking strain than any variety of commercial wrought-iron. It would appear then that after all we have not yet obtained a real ship-steel, but only a superior iron made by steel process, and called by courtesy *mild steel*.

Our own Admiralty may claim the credit of introducing mild steel for ship-building purposes in England. The French Government had used steel in the construction of ironclads; and in 1874 Mr. Barnaby, of the Admiralty, visited the French dock-yards and inspected several ships which were being built of it. The masted ironclad *Redoutable* was then building at L'Orient, and in her, steel was used for frames, beams, deck plating, plating behind armor and inner bottom; while the outer bottom plating and the rivets were of iron. The *Tempête* at Brest, and the *Tonnerre* at L'Orient, were also building, and steel was being similarly used in them, the steel for all these ships being manufactured at Creusot and Torre Noire. This metal took a breaking tensile strain of  $30\frac{1}{2}$  to  $31\frac{1}{2}$  tons per square inch, and the tested pieces elongated before fracture to the extent of 22 per cent. All the frames were bent by pressure, no iron hammers were used, and, if plates had been subjected to even light blows, they were immediately annealed. The cost of the angle steels was £27 per ton. A material which required to be so tickled with copper hammers, and was altogether of such a delicate character, was obviously unfit for shipbuilding, even in the Royal dockyards, where precautions might be possible which were altogether out of the question in a merchant ship yard. The solution of the difficulty was obtained in the production of a milder steel, which has been found by the Admiralty to be a thoroughly reliable material; but it must be ob-

served that they have instituted a most rigid system of tests to make sure that not only every lot of plates, but *every plate* supplied to them is what it professes to be. The metal first used for the Royal Navy was manufactured by the Siemens process, at the Landore Works, near Swansea, and was employed in the building of the *Iris* and *Mercury* at Pembroke Dock. These ships are unarmored dispatch vessels, of 3,750 displacement tons, and it was desired to build them of very light material, in order to obtain the high speed of  $17\frac{1}{2}$  knots. They have longitudinal and transverse frames, and the bottom plating varies from  $\frac{3}{8}$  inch to  $\frac{1}{2}$  inch. All the shell of the vessel, with the exception of the heel, stem, sternpost, and rivets, is of steel. The screw shafting which is hollow, is made of Whitworth compressed steel, and the barrel parts of the boiler shells are of mild steel. The frames were bent hot, and afterwards annealed; but the plates were, as far as practicable, bent cold. The Admiralty have now six corvettes, of which the *Comus* is the type, building on the Clyde, in which steel is used for the plating, the frames being of iron; the masts also are to be of steel. Within the last year several merchant vessels have been laid down in which mild steel is to be largely used; and Messrs. Thompson, of Glasgow, are now building a steel ship with steel rivets.

We have before adverted to tests instituted by the Admiralty for the purpose of securing uniformity in the material. It has always been the custom of the Admiralty to subject iron made for them to a series of rigid tests, which in the early days of their iron ship-building were carried out at the place where the vessels were built, and one clause of every contract with a shipbuilder was that he should provide on his premises an efficient testing machine. As a result of this the Admiralty are at present paying £15 to £16 per ton for (B) iron, used by them for shipbuilding, the market price of ordinary ship iron plates being less than half this amount. Besides the tensile test, hot and cold bending tests have been applied to both plates and angle irons. Of late years the tests have been made at the manufacturers, and have been conducted by

inspectors appointed for the purpose. The Admiralty had thus at hand a staff and an organization which could, with some extension, be made available for testing the new material. Their tests for *mild* steel have consisted of:

1. The tensile test, the minimum breaking strain per square inch to be twenty-six tons, the maximum thirty tons per square inch; the elongation before breaking to be not less than twenty per cent. in a length of eight inches.

2. That after having been heated and then cooled in water of a temperature not higher than 60° Fahrenheit, the steel shall stand bending to a curve of which the inside diameter is to be three times the thickness of the plate. A shearing is taken from *every* plate, not less than an inch and a half wide, and tested in this manner.

We have seen a list of consecutive tests of steel for Admiralty vessels of the *Comus* class, comprising eighteen plates tested with cuttings lengthwise and crosswise for tensile strength. The breaking strain was as often higher as lower for the crosswise cutting than for that taken lengthwise and varied from 25.6 to 32.8 tons per square inch; the elongation varied from 12 to 32 per cent., being for the most part well above the prescribed 20 per cent.

Turning now to the Mercantile Marine, and first to the action of Lloyd's Registry, we find that until November last there was no defined rule as to the employment of steel in shipbuilding, but each case was considered separately. In November, however, a report was published stating that a visitation committee had recently inspected the steel vessels building for the Admiralty, as well as others building for classification, and had also visited some of the leading steel works. As the result of their inquiries a circular was issued stating the conditions under which mild steel might be used as a material for shipbuilding. These are, first, that a midship section, &c., showing details of scantlings, be submitted in every case, and that tensile and other tests may be employed by the surveyors, every plate being supposed to take a minimum tensile breaking strain of twenty-seven, and a maximum of thirty-one tons to the square inch, with twenty per cent. of elongation pre-

vious to fracture. It was further prescribed that strips should, if heated and then cooled in water at 82° Fahrenheit, stand a similar bending to that of the Admiralty test.

In these requirements it will be noticed that the tensile strain is increased one ton, a difference justified by the practical results of testing. Further, it will be seen that an important feature of the Admiralty tests, the bending of a strip from *every* plate was omitted, the bending tests being only applied at the discretion of the surveyors. This omission was supplied by the issue of an amended circular on the 20th December, in which it is prescribed that all ship steel shall be marked by the manufacturers with a special brand, to indicate that strips from each plate so marked have been submitted to the bending test.

We cannot but think that the alteration in the amended circular was a wise and necessary measure. Former experience in metal made by steel processes has taught the naval architect that while a parcel of plates may for the most part be of excellent quality, and capable of doing their work in the structure of the ship, others made by the same process, and which show no outward difference, may be very faulty, and what makes the matter still worse is the risk that the fault may not show out till the plate is riveted in the ship. Manufacturers have been pretty successful hitherto with the new metal, but there is much yet to be learned before the manufacturer can be certain of producing parcels of material uniform in quality, and the naval architect must have much more experience of it before he can with prudence consent to make reductions in scantlings proportioned to the claims as to strength put forward; indeed, before any reduction at all can be made there must be some guarantee such as the brand proposed, that pains have been taken to ensure that *every* plate possesses the distinguishing characteristic of mild steel. As over-stepping the limit of safety in any particular may involve the loss of the ship, we would commend the whole subject to the notice of the Board of Trade, and to such of its officers as have practical shipwright experience, who cannot at this juncture give too much attention to the proper-

ties of the new material with which they will certainly have to deal. In fact, to vessels which come under the Passengers Act the benefit of a reduction in scantlings will be of most advantage, and we may feel sure that in building vessels of this class the conditions will be frequently complied with, and any consequent reduction of scantlings taken advantage of.

The advantage given for the use of steel instead of iron is to be a general reduction of scantlings to the extent of twenty per cent., subject to modifications in each case, consequent upon special considerations. Assuming the minimum tensile strength of iron used in shipbuilding at twenty tons per square inch, and the strength of the new material at twenty-six, a reduction of twenty-three per cent. in scantlings would secure the same strength; it will be found, however, that most mild steel will be over twenty-eight, and we think iron ship plate is often under twenty; and it will thus be seen that the Register Committee have secured a good margin, and are, as is most desirable, on the safe side. Already, as might perhaps be expected, complaints have been made that this reduction is not as much as would fairly meet the case, and that the requirements as to testing will cause much inconvenience. In the number of *Engineering* for 28th December last is a letter from a Clyde shipbuilder, in which he states that on a proposal for building a steel steamer the reduction of twenty per cent. was only granted for a portion of the structure, and that in some cases much less (14½ per cent. for the plating of bottom and sides) was allowed. He also complains of the regulations as to testing. The Committee have requested their surveyors to ascertain and report, "as early as possible, what facilities exist in the yard of the builders of this vessel for carrying out the tests required by the Committee in accordance with the circular." The writer goes on to say that "Lloyd's Committee know well there is not a testing machine in one out of a hundred shipbuilding yards in the kingdom," and then exposes the inconveniences which must result from testing and rejecting plates after they have arrived on the shipbuilder's premises, and urges that if the tests are to be

carried out at all, the best plan will be to provide for making them at the steel works.

The present provision for testing iron is contained in Section 3 of Lloyd's Rules for Iron Ships, and runs thus :

"Section 3.—The whole of the iron to be of a good malleable quality, to be subjected to tests at the discretion of the surveyors. Brittle or inferior material to be rejected. All plates, beam, or angle iron to be legibly stamped in two places with the manufacturer's name or trade mark, and the place where made, which is also to be stated in the report of survey."

It would appear by this that no tensile tests were contemplated by the rules, and as a matter of fact, but little more has been usually done in the way of testing iron than observing the way in which the material stood punching and bending, during which process, if it were of very inferior quality some indications of its badness would certainly appear. If, however, *mild* steel is largely used in shipbuilding, a series of rigid tests must of necessity be applied.

A comparatively small variation in the quantity of carbon or the presence of impurities is all the difference between mild steel and the unreliable material made by the same process, and this difference can, for practical purposes, only be ascertained by the tempering test which is to be applied to every plate, and which appears to be essential in steel shipbuilding. These tests must cause the market price of steel to be higher than would otherwise be the case, but there is no reason why it should be so much dearer than iron as has been anticipated. We believe the Admiralty have paid £15 per ton for their mild steel. That is less than they are paying for (B) ship plates, and we think there is every reason to believe that, with an increased demand, mild steel can be manufactured at a much lower rate. Its extended substitution for iron in shipbuilding will, of course, depend upon its price, whether it will be only so much dearer than iron, that the additional sum spent in first cost will be paid for by increased freight owing to the less weight of hull.

Another consideration connected with the use of steel for shipbuilding is its

durability as compared with iron. Of this, little can be said at present. Experiments have been made to find out the extent of corrosion in salt-water of steel and iron, but it is difficult to reproduce the conditions which obtain in actual ships, and it may be said that we know nothing for certain on the subject. Obviously, corrosion is a more important factor in steel than in iron ships. In the former the material in the first instance being thinner, the same amount of wasting will reduce the strength by a larger percentage. We have heard that in some of the very thin steel steam-launches recently built for high speed, deterioration of the material has arisen from an unexpected source. It was observed that the plates were pitted outside the vessel, and as they were only a sixteenth thick the pitting was nearly through them. No cause could be assigned for it except that the black oxide which forms upon the plate in rolling was electro-negative with regard to steel-plates, and thus galvanic action was set up. This may, of course, be prevented by "pickling" the plates in a diluted acid, and so removing all the black oxide before using them. We have heard that the Admiralty, with a view to provide against galvanic action from this or other causes, intend to "galvanize," that is, coat with an alloy of zinc and iron, all outside plates for ships. They can thus make certain that while there is any zinc alloy left, no galvanic action will affect the iron or steel; the only question is, whether the coating process will not injure the metal in other ways.

The Admiralty have not yet used mild steel rivets. They have, however, been used in shipbuilding on the Clyde, and it is said with good results. In one respect they are said to be superior to iron rivets as they hold the heat longer. It is urged against their use that they are liable to be spoilt by being over-heated or "burnt," when they become brittle and lose their malleability. With reference to this, the report of Lloyd's surveyors points out that iron rivets may also be spoilt, although at a higher temperature, and there is this advantage with steel rivets, that they unmistakeably show when they are bad and cannot then be used at all. It would appear probable that steel rivets may be harder than

iron ones, and would thus be liable to suffer from jarring strains, but we think on the whole it will be found best to use metal for rivets, of the same kind as the plates. One thing we would suggest; seeing that galvanic action appears to take place between metals of but slightly different composition, it may probably occur between steel plates and iron rivets and the result would be most serious.

The experience of the next few years will probably decide whether ingot iron made by steel processes will take the place of puddled iron as a material for shipbuilding. As the new material becomes better known it will become evident to what extent it may be trusted, and it is possible that our experience of it may justify a further step, the use of a decided steel with a high tensile strain as a material for shipbuilding. This must depend upon steel makers themselves; whether they can give the shipbuilder a thoroughly workable material with high tensile strain at a moderate cost, and above all a material which can always be trusted. The naval architect has a higher responsibility than the designer of land structures in which faults detected may be remedied at once; his work is subjected to severe and repeated strains, and must be capable of enduring them often for long periods. This is the reason why he will hesitate to use a material about which others may have no misgivings, and when he does use it, will exact good guarantees for its reliability.

Since the foregoing article was written, a further report of Lloyd's Special Committee has been published, from which we quote the following as enforcing our remarks upon the dangers attending the use of the new material unless every plate be tested :

"A most striking example was shown us at one of the works we visited, of the necessity for a bending test being applied to a shearing from every plate; and it also afforded a proof that the best test to apply would be a temper test, instead of an ordinary cold test. The firm in question was at the time manufacturing both soft and hard steel-plates, and in passing through the rolls a hard plate became substituted for a soft one. After passing through the rolls the

plates were annealed before being sheared, and when, after shearing, the hard plate came to be tested by the temper test, instead of the plate bending to the required curve, it broke off short. This led to the marks on the plate being examined, when the source of error was discovered. It had come from a charge capable of standing thirty-six tons to the square inch, and was never intended to be used for soft steel-plates."

The Committee also urge the importance of the tensile tests being made with

pieces of uniform length, the twenty per cent. elongation is to be in a length of eight inches, and if shorter pieces be tested, the percentage of elongation should be greater, since the elongation is greatest near the point of fracture, and thus a large percentage would be obtained in a short than in a long specimen of the same material. With regard to rivets, the last report of the Committee recommend that the steel employed in them should be very mild, and have the lowest limits of tensile strength.

## RIVER IMPROVEMENTS IN FRANCE, INCLUDING A DESCRIPTION OF POIRÉE'S SYSTEM OF MOVABLE DAMS.

By PROF. WILLIAM WATSON, Ph. D., late U. S. Commissioner.

WITHIN a few years there has been established between Paris and Auxerre a continuous system of navigation, with a minimum depth of water of 1.60 meters.

This has been accomplished by the erection of thirty-four movable dams with side locks, and also making three cut-offs: each cut-off has a guard gate at its head to keep out the flood water, and a movable dam without a lock is built across the river just below each gate.

The above operations have served to convert the two rivers, the Seine and the Yonne, into a series of navigable pools. Rivers so converted are said to be canalized.

In order to fully appreciate the importance of the improvement of the navigation by the establishment, on a large scale, of movable dams above Paris, it will be necessary to explain briefly the method of navigation heretofore in use on these rivers.

Formerly the water was raised in different portions of the river by means of movable dams (the construction of which will be presently explained); a part of one of these dams being suddenly removed, an artificial flood, called an *écluseé* or flash, was formed, which, in passing, afforded for a limited time, a draught of water sufficient for navigation.

The instant for opening each movable dam was determined by an empirical rule which was closely followed, and each dam was closed after the water had fallen below a certain level; usually during the summer, they were opened twice per week.

The velocity of a flash depends upon the declivity and sinuosity of the river, the number of dams, the volume of the flash itself, the wind, and the obstructions of the stream.

The boats carried by the flash generally go more rapidly than the flash itself, so that they can make short stops, to receive or discharge freight, and take the same flash again.

To understand the form and motion of a flash it is necessary to observe its velocity and depth throughout its whole extent; this has been done by M. Chanoine, at Laroche, and is shown in Fig. 1. This figure gives the level of each point of the longitudinal profile with its corresponding velocity. It shows that the velocity varies from one point to another, and that the top of the flash travels more rapidly than any other point, whether before or behind it. For this especial flash the velocity of the water is 1.33 meters per second for a length of 2,394 meters occupied by the top, while at 3,474 meters in front the velocity is only 0.53 meter; and it is 1.15 meters at 4,482 meters behind; thus at each in-

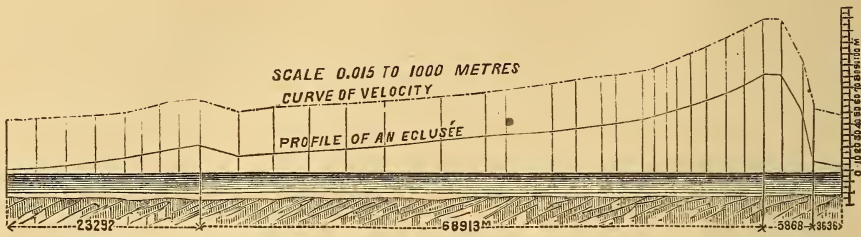


FIG. 1. — Form of an *écluse* or flash. Curve showing its velocity at each point.

### BASSEVILLE BARRAGE.

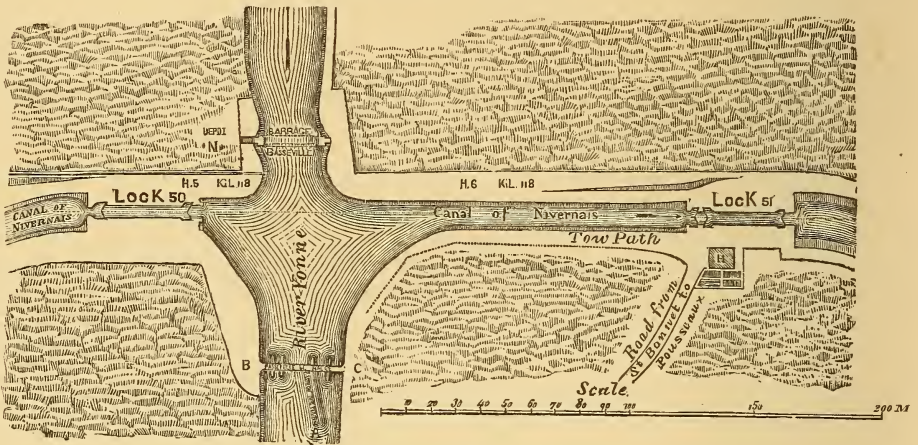


FIG. 2. — Plan of the crossing of the Yonne River, by the Nivernais Canal at Basseville.

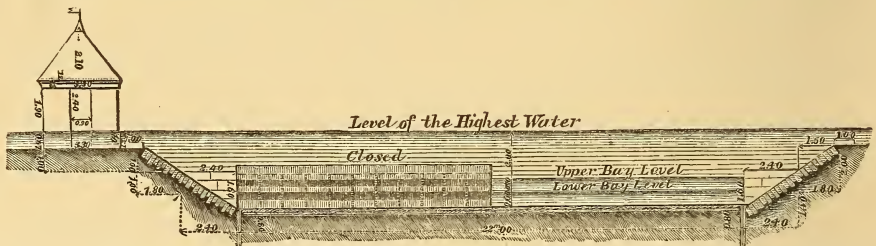


FIG. 3. — Elevation of the Basseville barrage, showing half the barrage closed with the fermettes raised, and the other half open, with the fermettes lowered.

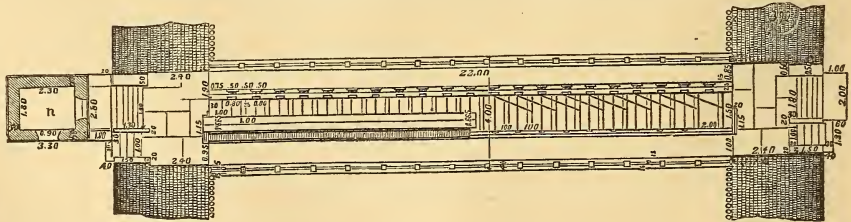


FIG. 4. — Plan of the same.

stant the highest section of the flash is thrown forward upon the section immediately preceding, which moves at a slower rate. This shows why a boat on the top of the flash will move faster than the flash; but if the boat is in that part of the flash where the velocity is less than 1 meter and behind the crest it moves slower than the flash and finally falls entirely behind it. We may estimate the effective duration of a flash to be one-half the time it actually takes to pass a fixed point.

Each movable dam remains open only a short time for the passage of the flash and is immediately closed again to collect the water for the following flash. This closing produces below the dam an abasement of the level of the water which is designated by the name *affameur*. Every flash is thus followed by an *affameur* which is felt at a great distance down the stream; and for from twelve to twenty-four hours following, the water is below its ordinary level; for this reason the ascending boats are nearly or quite empty. Nevertheless this navigation, imperfect as it is, has rendered for three hundred years signal service for the economical transportation of wood etc., at a time antecedent to the establishment of other means of easy and rapid communication. In 1866, from Laroche to Montereau, the freight in boats was 270,699 tons, by rafts 179,230, descending; ascending freight 5,518 tons; total 455,750 tons.

As early as the middle of the last century attention was called to the diminution of the volumes of the flashes, and the remedy proposed was the construction of large reservoirs to accumulate the winter waters, in order to augment the flashes in summer. One of these, the reservoir of Settons with a capacity of 23,000,000 cubic meters was finished in 1858, and supplied for each flash a volume of from 500,000 to 700,000 cubic meters. But this flash, augmented by the water from all the dams of the Yonne and its affluents above Auxerre, encountered no further obstacle below the latter point, and went on diminishing to the Seine, upon which its effect was very slight. Only half the appropriation had been spent when the inefficacy of the remedy was perceived. In reality the progress of industry and

commerce, as well as the extension of railways, required the barges on the Seine and Yonne to be greatly improved, which was not possible until the navigation should be made continuous with a sufficient draught of water for loaded barges.

At this juncture the Government, adopting the views of M. Cambuzat, ordered the construction of the movable dams referred to at the beginning of this paper. These dams, or barrages as we may call them, are of several kinds, one of the simplest is Poirée's needle barrage known as *Barrage à fermette de M. Poirée*.

#### POIRÉE'S NEEDLE BARRAGE.

*History.*—The following is a brief outline of the history of the invention of this barrage. At Basseville, where the Nivernais canal crosses the Yonne at the same level (Fig. 2), it was necessary to erect a barrage, which, while it maintained the level of the river at a height sufficient for navigation, could be so opened as to leave the original section of the stream wholly free for the passage of flashes carrying rafts and logs.

The old passes of the Yonne gave M. Poirée his first idea; these passes were closed by a horizontal swinging beam supporting a vertical screen composed of a number of wooden battens called needles, each about 2 meters long and 0.475 meter square. Mr. Poirée first made a *projet*, consisting of five of these passes placed side by side; next he conceived the idea of replacing the piers which separated the passes, by iron frames placed parallel with the current; then he made these frames movable about their bases, so that in lowering them upon their bed, they should completely disappear, and thus leave the original section of the river intact; finally, he increased the number of the frames, and brought them close together in order to diminish the pressure which each had to sustain, and thus avoid any risk either of rupture or displacement. On account of the resemblance of these frames to the trusses of a roof (*fermes*) he called them *fermettes*, a name which they have since retained.

#### DESCRIPTION OF BASSEVILLE BARRAGE.

In order to give a clear idea of this barrage, I cannot do better than repro-



## BASSEVILLE BARRAGE.

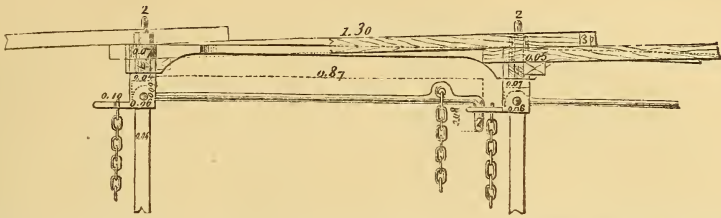


FIG. 12.—Elevation of the details for uniting adjacent fermettes, seen from below.

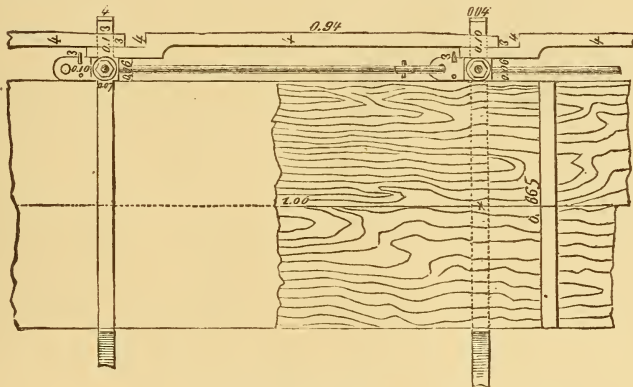
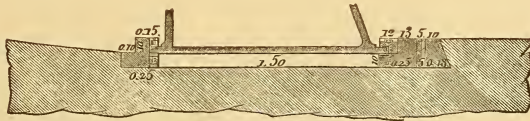


FIG. 13. Plan of same.

*Fig. 14. D. Section on AB.*



*Fig. 15. D. Plan*

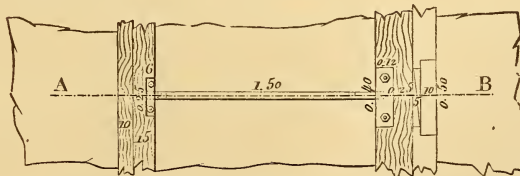


FIG. 14. — Transverse section of the gudgeons and bearings of a fermette.

FIG. 15.—Plan of the same.

duce a description given by the inventor, in a lecture at the School of Roads and Bridges at Paris: Figs. 2, 3, 4, 5, represent the situation and arrangement of the first needle barrage ever erected. It consists of a succession of iron frames (Fig. 5) called *fermettes*, placed parallel to the current and turning around their bases in bearings which are firmly attached to a carefully prepared bed. The *fermettes* when they are erect, are united by bars with jaws or notches at their extremities (Figs. 8 and 9). The needles form, by their union, a screen which rests below, against the sill, and at the top, against the *fermette* bars, placed near the level of the water, which the barrage is intended to maintain. Each *fermette* is trapezoidal; its bases are horizontal; the lower one is terminated by gudgeons which are secured by two cast iron bearings (Fig. 14). The upper bars support a foot-bridge used by the lockman to work the barrage (Figs. 5 and 13): the up-stream side is vertical, the down-stream side is inclined; the interior is strengthened by one or more braces according to the pressure it has to support.

At the head of the *fermettes* is a bolt with a washer at its upper part; against this bolt rests one end of one of the up-stream coupling bars (Figs. 8 and 9); the lower part of the bolt holds on one side an eye-bar (Figs. 12 and 13) into which fits the hook of the rod uniting this *fermette* with the preceding one, and on the other side the hooked rod which unites it to the succeeding *fermette*.

#### *Weight and dimensions of a fermette.*

—In order that the *fermette* may be easily maneuvered by two men they are placed one meter apart: they are 1.52 meters high, 0.70 meter wide at the top, 1.50 meters at the base, and weigh 90 kilograms each—not including the bars and rods; the thickness of the iron is 0.04 meter.

*The operations for closing the barrage* are as follows:—Two men raise the first *fermette* by the chain which unites it to the abutment and put its hook into the eye-bolt fixed in the masonry; next they place the two planks of the flooring, and then connect the *fermette* on both sides with the abutment by means of the notched coupling bars; they operate in

the same manner for the following *fermettes*.

Having thus established the frame the two men proceed to place the needles; first, at intervals, so as to break the current, then close together, so as to render the screen as tight as possible.

When it is required to *open the barrage*, the men remove the needles and place them upon the down-stream portion of the service bridge; if it is also required to lower the *fermettes* they carry the needles to their store-room *n* (Fig. 4); then they take off the coupling bars and the flooring of the last interval; next they raise the hook which unites the last *fermette* with the preceeding one, and lower it slowly to its place by means of the chain attached to the hook. The same operation is repeated for each interval.

When a *fermette* is lowered and its chain stretched tight, a peculiar ring-shaped link, previously placed at the proper distance, should be found at the right of the eye-bar of the upright *fermette*; if this is not the case, the lockman is warned that the *fermette* is not entirely down.

*The time per running meter* to raise the *fermettes* and place the needles is about 90 seconds:

To open the barrage by removing the needles 30 seconds:

To remove the needles and lower the *fermettes*, 50 seconds.

THE Alberta, Royal yacht, made a trial of her machinery lately in the Solent, when advantage was taken of the occasion to try a new log, the invention of Mr. Froude, with which it is intended to test the speed of vessels of war when undergoing their six hours' run. The log itself is not unlike the patent log known as Massey's, but the fan is much larger and has been formed upon strictly scientific principles. It was connected to a registering apparatus inboard by Kelway's electric gear, by means of which the work performed by the log in the water is recorded on deck, thus dispensing with the necessity of hauling in the log to ascertain the distance travelled through. As tested on the measured mile the error of the improved Massey was found to be only one-hundredth part of a knot.

## A MORAL AND ECONOMIC ASPECT OF THE SEWAGE QUESTION.

From "The Builder."

NEW excitement about the sewage outfall and its effect on the Thames, has developed into a very pretty dispute (we will not say "quarrel") as it stands, even if it lead to no more definite result. In all such cases there is a certain amount of talk and recrimination to be got rid of,—a kind of waste gas driven off by combustion,—before we come to the solid matter of the point at issue,—the question, what is to be done? We may even yet be a good while in getting to any practical result; but it is something if we can even make a step or two in the direction of the right theory of action. What is, in fact, needed, in regard to this and some questions of social economy of the day, is to bring theory and practice into closer relation one with the other. The main drainage works for London were practically, no doubt, a great piece of engineering skill and perseverance, involving great outlay and much practical skill in investigating and testing materials so as to produce a permanent result; yet all this labor and expense is, as we think people are beginning to see now, to a great extent, thrown away, through being based on a mistaken and incomplete theory to begin with.

Two points have struck us amid some of the paper warfare which has been started on the subject, by no means of equal importance, but which both serve to show the very partial view of the subject which is taken by those who are officially most concerned in it. One is, the exclusively legal aspect in which the matter is treated by the Board of Works or by those who are their spokesmen or champions before the public. One of these chivalrous defenders of the Board and its action seemed to think he had made quite a point in favor of his clients by showing that they had not, as some of their opponents asserted, contravened the provisions of the Rivers Pollution Act; that there was a clause in that Act specially exempting the case of the Thames and the main drainage works from its operation: furthermore, that it

was a mistake to suppose that the Board of Works were under any obligation to deodorize the sewage before turning it into the river; except in regard to temporary outfalls until the main drainage outfall could be completed. But this is only proving a little too much: only, at the most, shifting the blame on to other and, perhaps broader shoulders; or possibly we may go further and say that such a fact only shows that the Board and their engineers were shrewd enough to obtain legal sanction for shirking the most serious part of the problem, in order to apply with greater readiness a remedy of which it might have been prophesied (was, in fact, prophesied) that it would work no radical cure. Looking at this defence, based on their legal position, one cannot help asking, under what exercise of influence in high places it came to pass that the Metropolitan Board of Works were permitted to form an exception to the operation of the Rivers Pollution Act in the case of the most important town on the most important river in England? The result simply comes to this, that the public and their Parliamentary representatives were deluded into the belief that a certain scheme, carried out at enormous cost, would prove an efficient solution of the question, "What is London to do with its sewage?" And that not only is it no solution, but is surely though slowly building up the original danger in a roundabout manner; but also that any exercise of common foresight on the part of those who carried out the scheme ought to have led necessarily to the conclusion that this would be the result. Yet, for all this, it seems to be considered a sufficient defence to say that the Board have done all that the law required of them. They do not recognize any moral or sanitary responsibility in the matter; they do not seem for a moment to entertain the idea that they, as the responsible body entrusted with the improvement of London, were under a moral obligation to find out the best method and carry it out; they have not

asserted, or their friends have not done it for them, that they consider the sewage difficulty on every side, went to the root of the matter, and saw no better solution than that which has proved such a failure,—not at all: they are content to say that they were under no legal obligation to find a solution; that, like “the unprofitable servant” in the parable, they had done that which it was their legal compact to do, their “duty” only in the narrowest and most official sense. But they cannot morally (whatever they may do legally) shelter themselves behind the law in this way. On such points the Board of Works, being specially and immediately charged with these great sanitary operations, were bound to know more about the subject than any one else, to correct or supply the defective requirements of the law, not to shelter their costly half-measures behind it. To adopt the latter position is as reasonable as it would be to say that a man deserved no blame for keeping a cesspool close to his house property, though knowing it to be a nuisance, because the sanitary inspector was deficient in knowledge, and did not compel him to remove it.

That this merely legal responsibility is the view taken by the Board of Works of their position, we have had further confirmation in the tone they have openly and explicitly adopted in regard to the almost more pressing question, because dealing with a more instant though transient evil, of the Thames floods; in regard to which they have drawn upon themselves something more than a hint from the Home Secretary that they may be compelled to do their duty or resign their privileges. But leaving this point at present, which we allude to only as confirming the justice of our strictures in regard to the slack sense of responsibility on the part of the Board, we must say a word on another aspect of the question which has been incidentally suggested, but deserves far more consideration than it seems likely to receive. Among the arguments brought forward to justify the legal position of the promoters of the main drainage works, the following quotation from the Local Government Report of last year has been adduced:—“That towns situated on the sea coast, or on

tidal estuaries, may be allowed to turn sewage into the sea or estuaries, below the line of low water, provided no nuisance is caused; and that such mode of getting rid of the sewage may be allowed and justified *on the score of economy.*” (The italics are our own.) The application of this to the particular question at issue is of course that Crossness comes under the conditions thus described in the Report. What we wish to draw attention to is the defence which is made of this way of getting rid of sewage as “economical;” and what is meant by that is (for in no other sense can it be true) that the particular town which gets rid of its sewage in this manner saves the cost of transportation of the sewage, and of the labor required for this, to a place where it can be made useful. Now, just consider what an utterly narrow and one-sided view of “economy” this is. Economy, if it means anything, means a wise saving and husbanding of resources, not the keeping of injurious things about one to save the cost of getting rid of them. Even as regards the special town which thus turns its sewage out on to its shores, there is, therefore, no real economy; a permanent danger to health is thus established, which in the case of a small town favorably situated in regard to tides, may, perhaps, be very slight, but which, it is to be remembered, is always tending to increase. But this economical statement of the matter becomes still more unphilosophical in its aspect when we take a broader view of the subject. No doubt it must be admitted that the golden promises about the national wealth to be derived from the utilization of sewage, which were too enthusiastically and prematurely made when the idea of utilization first occurred, can hardly be fulfilled; ratepayers must modify their ideas as to what can be expected in the way of return from that source, and as to the expenditure involved in it both relatively and positively. Still, there are the facts, which may now be taken as almost conclusively proved, that sewage is a nuisance and a danger when passed into rivers, or even into the sea in close proximity to a coast town, while it is innocuous when properly treated as manure; that in the former case it is clear loss, while in the latter case it has

a certain "food-producing" power not inconsiderable, though not equal to what used to be supposed. Admitting, therefore, all that has been urged against irrigation, that the farmers will not take the sewage, that it cannot be sold at remunerative prices, and so on,—it must nevertheless be concluded that if no return is obtained from irrigation, it is a wise economy notwithstanding to expend money in putting sewage where, at all events, it does good rather than harm, and making a step towards that ideal economy of physical science which is inferred in the saying that "dirt is only matter in the wrong place." And we may suggest in passing that if we can arrive at an organized system of sewage distribution over the land there is really no reason why the opposition of the farmers,—a class of the community always averse to novelty and not given to philosophize on the reasons of things,—should not be got over by compulsory legislation, just as reasonably as such legislation has been proposed in regard to the irrigation of India, both schemes being considered as concerned with the good of the people at large, to which private inclinations must bend. It is certain that, to carry the irrigation theory into practice in the case of sewage, and more especially in regard to London sewage, a systematized machinery of distributing on a large scale would be required; we say more especially in regard to London, because the amount to be dealt with is so great, and it would be necessary to provide for its distribution over so wide an area, the circumstances being quite different from those of an ordinary-sized town; and as it is pretty certainly ascertained that, at the worst, town sewage is more or less productive as a manure, and can be used in this way with effect in its agricultural results, and without being obnoxious in a sanitary point of view, the question to be considered is whether it is not worth while to set at once about the framing of a comprehensive system of sewage distribution, and the organization of the machinery of collection and transportation.

No doubt this will be a very costly operation to begin with, and will require not only machinery, but labor, the cost of the latter being a continuous item.

And it is in reference to this point that we wish to recommend to those who think it so much more economical to run sewage into the sea, an aspect of the labor question, which is worth considering in connection with the subject. Society is dragged upon by the clog of a very large, and we fear not a decreasing, pauper population; a portion of which consists of those, no doubt, who would always be paupers by option, as long as our inconsiderate and ill-organized charities give them an easy means of being so; but of whom, again, there is a large proportion who would gladly work if work could be found for them. It is one of the greatest difficulties encountered by those who are specially concerned in the work of helping their poorer brethren, especially in the present "slack times," to find any work for those who are willing to work, and who would do anything rather than sink into pauperism. So great, indeed, is the difficulty, that there is even a temptation to, as we may say, *invent* work for these unfortunate classes, and thus save the outward aspect of pauperism, though in reality adopting another form of it. And therefore a work which requires to be done for the general good, and upon which those who are now perforce idle and dependent, could find the opportunity for selling their labor with advantage to themselves and the community, ought really to be considered almost a godsend. If it becomes necessary, therefore, to organize sewage distribution on a large scale (and without some regular and extensive system it can hardly be efficiently carried out), this might really also be a step towards that organization of labor on a large scale which is the only permanent remedy against the existence of distress and pauperism. And therefore it seems to us that when people talk of "economy" as an element in favor of the running of sewage to waste, they should take into account, *per contra*, not only the possibility that sewage distribution works may be made to pay their way if properly managed (and, in spite of some disappointments, the contrary is not proved), but also the opening afforded for employing labor on a great scale,—labor which is now idle,—in a way worth paying for in itself, and which would even recoup a great deal of

its own cost by the reduction of what now goes to the support, on charitable grounds, of those who have no sale for their labor: not to speak of the incalculable social advantage of being able to turn a number of idle hands to work which would be directly for the *wealth* (as distinguished from "riches") of the whole community. We have sought on

more than one occasion to call public attention to the existence of "lands that want hands." The proper treatment of the sewage question would involve work that wants hands, and provide us with a very important and permanent counterbalance against the drag on society, to put it on no higher ground, of hands that want work.

## ON TUBBING; OR STOPPING BACK FEEDERS OF WATER MET WITH IN SINKING SHAFTS.

By MR. RALPH MOORE, H.M. Inspector of Mines.

From "Iron."

TUBBING is the name applied to a wood or iron lining placed in shafts for the purpose of stopping back water. The theory is that the porous sandstones found in the coal-measures are pervious to water coming in from the surface at their outcrops, while the clays or shales are impervious and will not allow water to pass through them; the sides of the shaft are therefore cased or lined where the water-bearing strata are met with, so that the water may not run into the shaft, and require to be pumped to the surface. Although the practice is frequently resorted to in English mining it has not been much adopted in Scotland, and it is thought that a short description of one of the methods of putting it in may not be unacceptable to the members of this Institution. The base of the tubing is the wedging crib which consists of a hollow iron ring 16 inches broad and 6 inches deep, metal inch thick. It is cast in segments about 4 feet long, and the inside diameter is the same as that of the pit. The space between the wedging crib and the sides of the shaft is made water-tight with wooden wedges, and the wedging crib is the foundation of the whole structure.

Upon the wedging crib are placed plates or rings of tubing. These are also made in segments, with flanges in 4 feet lengths, 2 feet deep, metal about  $\frac{3}{4}$  of an inch thick, dependent on the pressure to be resisted. These rings of tubing are piled one upon another as

high as the water will rise behind it before finding its level.

The mode of putting in the tubing is as follows:—The shaft to be tubbed is made circular, and before the tubing is put in, the water met with is raised by pumping machinery in the usual way.

After the water-bearing strata have been sunk through, the wedging crib is laid in the first bed of hard "faikes" or "blaes" which is met with. The pit is widened out, and is generally sunk three or four feet below this point so that the water may not trouble those putting in the tubing. The pumps must be kept well into the shaft, so that the workmen may get easily at the back of the crib for the purpose of wedging. In sinking past the place where the crib is to be laid, care must be taken to have the pit the exact size that it is intended to be, and no shots ought to be placed except in the center or within three feet of the sides, lest they shatter the strata near the crib seat. A scaffold is then placed across the pit so that the men may more conveniently cut the crib seat and wedge it securely. It is the main stay of the tubing, and everything must be done with watchfulness and carefulness so that the work may be well done; this cannot be too strongly impressed upon all engaged upon it. The bottom and sides of the crib seat require to be cut water level and plumb, and this requires to be done with great caution. It is cut 3 inches wider than the breadth of the

crib, and this space requires to be cut all round to a center line, and perfectly plumb and water level. It is cut out first on the back and sole with picks, as near to the size as possible, and then adzed smooth to take out the pick marks. The adzing must be done until it is as smooth as glass, and all the pick holes taken out. There must be no hollows in it. If there should happen to be any faulty place the faulty place is cut out. The great importance of this will be at once seen, for there can be no repairs made upon the wedging crib afterwards, and if it is not water tight another crib seat must be cut out a few feet below and joined to the first. When the crib seat has been satisfactorily cut the wedging crib is laid upon it as follows :

First : Pieces of half-inch fir deal called sheathing, the full width of the crib, are placed endways to the pit, all round. Upon this the crib is laid, trained carefully by the center line, pieces of half-inch oak sheathing being placed at the ends of each of the segments. The crib so laid is half an inch wider in diameter than the pit, but the wedging brings it to the correct size. When it is placed in position, pieces of wood called gluts, made to the exact size to fit in between the back of the crib and the wall, are driven down to the full depth of the crib, two pieces in each segment to keep it in position. When this is done the space all round is filled with similar pieces driven close together.

The crib is now ready for wedging, but in order to prevent it from rising in front, props are put from the crib to the strata above. The first round of wedging is made with wooden wedges, 6 inches long by  $2\frac{1}{2}$  by 1-3rd inch, the front of the wedge towards the center of the pit, a hole having been first made with the wedging chisel for the wedge to be driven into. The wedging chisel is generally made 6 inches long and  $2\frac{1}{2}$  inches wide at the broad or chisel part. The wedges are driven carefully, so that they may reach as far in as possible, and if they do not go in their full length they are cut off with the chisel, level with the top of the crib. The wedging is carried regularly round, and continued until the wedges refuse to be driven in, and then chisels an inch wide and wedges to

correspond are driven in until the wedges will scarcely enter. It usually takes eight or ten rounds of large wedges and two rounds of inch wedges to complete the wedging. The last course is a course of iron wedges driven in angleways, which makes the space between the back of the wedging crib and the sides of the shaft perfectly water-tight.

The wedging crib is now ready for the segments, which are placed in rings. Fir sheathing, the breadth of the segment and one-half inch, is laid on the top of the wedging crib. The segments are now laid on, pieces of sheathing being placed at the joints. The circle of segments is kept in its place by long wedges driven down between each segment and the wall. When the first circle has been fairly placed, the space behind the first round is filled up with Arden lime or other cement, so that if there are any leaks in the wedging crib the lime may assist in silting them up. Another range of sheathing is laid on and the next circle of segments is laid on, the vertical joints being broken like mason work, sheathing being put in the end joints as before, and tier after tier is put on until they are above the height to which the water will rise. After the whole has been put in and joined, the wedging of the segments is commenced. This is done with ordinary wooden wedges,  $4\frac{1}{2}$  by  $1\frac{1}{2}$  by 1-3rd, going regularly round from the bottom upwards, twice up and once down, till it is perfectly tight. Until the wedging is completed the water runs through the plug holes in each plate. After the wedging is completed the holes in each segment are plugged up, and the whole is perfectly tight. In some cases instead of the segments being carried up as far as the water will rise, a wedging crib is placed at some convenient point above the water-bearing strata, and the segments closed up on it. In this case the water is confined between the two wedging cribs and between the two beds of shale or water-resisting strata in which the wedging cribs are placed. This is called close-topped tubing, and is by no means so simple as the others, but the process is the same. It is usual in close-topped tubing to put on a valve so that any air may escape freely while it is filling. Wood is frequently used instead of iron,

but in all cases the wedging crib requires to be specially attended to.

Tubbing, as described, was put in at Allanshaw, near Hamilton. The shaft was 14 feet diameter, and reached the Ell coal at a depth of 118 fathoms. At a point about 60 fathoms from the surface a feeder of water 1000 gallons per minute was met with in a spongy sand-

stone. It was effectually tubbed back, very little more water was found below this point, and the pit was afterwards sunk without a pumping engine. The total cost of labor and wood for 8 fathoms of tubbing at Allanshaw was £177. It was put in by the manager, who had never seen tubbing put in before.

## EXPLANATION OF A METHOD OF PREVENTING CORROSION OF IRON AND STEEL, AS APPLIED TO NAVAL AND MILITARY PURPOSES.

BY PROFESSOR BARFF.

"Journal of the Royal United Service Institution."

I THINK it is desirable, before entering into a description of the processes which I have undertaken to explain to you this evening, that I should, for the benefit of those who are not acquainted with chemistry, go into the nature of the changes which iron undergoes when it is submitted to the action of oxygen gas. I feel this to be more important since my process has become somewhat generally known, and interested persons have applied to me to explain to them its nature and its various applications. I have found a very great difficulty in making those who are otherwise well instructed understand the process, from their ignorance of the chemical reactions which it involves, and of those, connected with iron itself, which it prevents. Many of you here present, I have no doubt, understand thoroughly all that I am now going to treat of, but there are also others who I most earnestly wish to make thoroughly comprehend this process, who have not got that preliminary knowledge, and who must have it to some degree, in order that they may be able to understand the principle of the process, and its applications to iron. I shall, therefore, take the liberty, Mr. Chairman, with your permission, of endeavouring to make my explanations more clear by the use of a few simple experimental illustrations.

Iron in perfectly dry air does not rust at all; that means to say that the oxygen of the air will not unite with it. I have

here an illustration of this, for in this bottle is a piece of bright iron wire which has been placed there for some days. In the lower part of the bottle you will notice a thick liquid. It is called oil of vitriol, and it has the property of absorbing moisture, so that by it the moisture of the air in this bottle has been absorbed, and we speak of the air as being perfectly dry. You notice that the iron is not rusted at all. Now I have a similar piece of iron in a similar bottle, and this contains none of that liquid which is able to absorb moisture. The iron has been in the bottle for exactly the same length of time, and you notice that it is rusted, for the air in this bottle is moist; that is to say, it contains water-vapor in suspension, just as does the air in this room. Now I take another piece of bright iron wire, and I make it red-hot in the flame of this lamp, and you notice that it is covered with a black film, and this film is an oxide of iron, analogous to that which is formed in smithies, where hot iron is beaten into shape on the anvil. Around the base of an anvil in any blacksmith's shop you will notice a number of scales lying about, which persons are generally accustomed to consider as pieces of iron which fall from the iron when it is beaten. They are not iron, but oxide of iron. Now, in the first instance, the oxide is of a reddish color, and is known by the common name of iron-rust, and the other is black. Now, Gentlemen,

bear with me for one moment. I have here in this bottle a green solution. It is a solution of what is ordinarily known by the name of green vitriol. Now, green vitriol is a compound of another oxide of iron with sulphuric acid. Certain substances are able to take away the sulphuric acid from this vitriol, and this oxide of iron, which is insoluble in water, is thrown down as a precipitate. I need not tell you the names of these substances which have this particular property. It is simply enough for me to show you the result. I now add some of this colorless liquid to the green solution, and you see a dirty green substance is precipitated. I will throw this upon a plate, and it will begin to change color. It will pass from dirty green to yellow, of a more or less reddish hue. It is manifest that a change of some kind must take place in its composition, in order to produce this change of color, and the change is caused by the fact that the oxygen of the air has united with it, and has changed it from the lowest oxide of iron into the highest. The composition of the dirty green precipitate is as follows: 56 parts by weight of iron and 16 of oxygen, and when it becomes yellowish-red the composition of that body is twice 56 parts by weight of iron, and 3 times sixteen by weight of oxygen. That is to say, the iron has taken up half as much oxygen as it had before, and hence that oxide is called a sesqui-oxide. I have here in these two tubes some of this sesqui-oxide. In the one tube you will notice that the color is bright yellow, and in the other that it has approached more or less to a greenish hue. The tube in which this greenish substance is, contains a piece of metallic iron, for into both tubes the same yellow substance was originally placed mixed with water; the iron in the one tube has commenced taking away oxygen from the sesqui-oxide, and is gradually reducing it to the state of the lower oxide. From this experiment you will perceive that the lower oxide of iron, when it is in the moist state exposed to air, takes up more oxygen, and that in the moist state, when acted upon with iron, it gives up oxygen to the iron. You will now be prepared I hope fully to understand the process which takes place when iron rusts. Moisture must be present, then

the oxygen of the air unites with some of the iron forming the lower oxide, the same as that which I have just precipitated from the solution of green vitriol, and this, when exposed to air, becomes the higher oxide, and this higher oxide in the presence of moisture gives up some of its oxygen to the metallic iron, becoming the lower oxide again in part, and this absorbs more oxygen from the air, and so the process goes on continually until the iron gets oxidized through its substance, or, as we in common parlance say, rusts away.

To return now to the oxidation of iron when heat is applied. If moisture be absent, only the black oxide is formed, and this black oxide is incapable of giving up its oxygen to iron, or of, under any circumstance, taking more oxygen from the air.

I have arranged some experiments to illustrate this I hope satisfactorily to you all. In a hard glass tube, connected with an apparatus consisting of a flask in which steam is generated, and which hard glass tube is heated throughout its length in a gas furnace, I have placed some iron filings and iron wire. I will pass the steam through this tube, and will collect in a bottle the hydrogen gas which is given off. You will notice that the iron filings and the iron wire have both assumed a dark-grey color. This is owing to the conversion of their surfaces into the black oxide of iron, and the hydrogen gas you will see presently burn with its characteristic non-luminous flame. Now, if this iron wire be rubbed with the finger a portion of the black oxide can be removed, and if both wire and filings be exposed to moist air they will rust where the oxidation is not complete. In this bottle iron filings and wire, which were similarly treated a few days ago, have since been exposed to the air, and you will notice that they have rusted in part. I will now, instead of allowing the steam to pass directly into the glass tube, cause it to circulate through a coil of pipe which is placed in the center of this little charcoal furnace, which is now perfectly red-hot. In its passage the steam will become dry or superheated. I will now let this steam pass into this other tube with which I have replaced the former one, which contains pieces of bright iron wire, and

likewise some iron filings. The superheated steam will form on the surface of the wire a coherent and adherent coating, which will not rust on exposure to air. I don't mean to say that in the short space of time this iron has been exposed an absolutely perfect coating will be formed, for in practice iron to be rendered non-corrosive is usually exposed to the action of superheated steam from four to ten hours. In this case hydrogen gas is given off as in the former.

It is very interesting to me to know that several chemists, skilled in the application of that science to the arts, have endeavored to effect, without success, what I, by a lucky chance, have been fortunate enough to accomplish. These gentlemen have related to me their experiments made, in some cases ten and in others twelve years ago, with a view to convert the surface of metallic iron into the black oxide, so as to prevent corrosion, and they have all told me that they failed at one particular part of the process, for they were not able to get a hard and coherent surface. It was my good fortune to make an observation in one of my experiments, after many, many failures, which opened my eyes to the reasons why all my previous experiments had failed, and now tells me how it was that these gentlemen failed before me. My early experiments were made in an iron tube, about ten inches long by two inches diameter, the two ends of which were closed with iron caps, and into it, at each end, an iron pipe was fastened, the one for the passage in of steam and the other for the outlet of hydrogen. Into this small chamber pieces of iron were put, and the chamber itself was placed in an ordinary furnace. Steam was generated in a glass flask, and was allowed to pass into it for a short time, the iron chamber being heated to a red heat: I found that the iron was coated with black oxide, that hydrogen gas escaped from the exit tube, for I collected and burnt it. The black oxide was more or less adherent to the surface of the iron. Sometimes it was so pulverulent that it could be dusted off. At others it seemed more firm and coherent, but on exposure to air, the iron rusted and the black oxide was thrown off in powder or in flakes.

On one occasion, on taking out a piece of iron, after it had been heated, from the iron chamber, I noticed that at one part there was a brownish-red tint upon it. This immediately gave me the idea that some of the red oxide of iron was produced on its surface, and that this was, in some way or other, mixed with the black oxide. The idea immediately struck me that, owing to the presence of moisture in the steam, some red oxide was first formed, that it was afterwards reduced to metallic iron by the hydrogen set free on the further action of iron on the steam, and that this reduced iron was eventually converted by the steam into the black or the magnetic oxide. Further observation tended to confirm and, I think, eventually to prove that this surmise of mine was correct. For I immediately had a coil of iron pipe made and attached to the iron chamber, between it and the ingress tube, and this coil was so constructed that it could be put along with the chamber into the furnace, and so be heated to a high temperature. The steam therefore passed slowly through the red or white hot coil of iron pipe previously to its coming in contact with the iron to be acted upon, and nearly the first experiment that I made with this new apparatus showed me that a hard coherent coating adherent to the iron could be produced. From that time to the present, the only difficulties which have attended the carrying out of this process have been of a mechanical nature, and have been step by step overcome, so that now, with almost absolute certainty, we can charge one of our furnaces and bring out all the specimens with a satisfactory coating. Sometimes we may have a few failures, and these all go to prove the fact that my theory, already stated, must be true. For, if the steam be turned into the chamber when it is not sufficiently hot to keep it in the state of dry steam, some of it gets condensed, water-vapor is formed, and this produces a result similar to that which I have explained to you as happening in our earlier investigations. I have to render thanks to my friend, Mr. Hugh Smith, for the help he has given me in carrying out this part of the application of my process. He has superintended the muffle in the treatment of all the experiments on the

table. I have already mentioned to and shown you that the black oxide of iron is formed when iron is heated in atmospheric air; but, when it is so formed, it never adheres completely to the surface on which it is produced, and always on exposure to moisture comes off, a coating of red rust being formed around and beneath it. Therefore, we found it essential and necessary to expel all atmospheric air from our heating-chamber before we allowed the entrance of superheated steam.

I may say that there are two conditions absolutely necessary to success. The one is that no atmospheric air be present, and the other, that the steam be perfectly dry. The iron before being submitted to the action of dry steam must be perfectly clean, that is, it must have no spots of red rust upon it, for if it have, the results which I have previously explained to you will be produced in these particular spots, and after exposure to air rust will appear upon them. But you will see from the specimen to which I now call your attention, that this rust is perfectly circumscribed and does not extend laterally, nor is it formed under the coating of the black oxide. So that if some large article, such, for instance, as a girder, were treated, and if many spots rusted after a time, owing to the causes which I have just explained, the strength of the girder would not in any way be impaired, as the rust would be perfectly localized and would not spread. This bar of iron was treated all over; with some difficulty I rasped off a portion of its surface, and the whole was exposed for a very considerable time through the late heavy rains on a lawn. You will perceive that the half from which the black coating has been removed has rusted completely, and that the rust has eaten its way a considerable depth into the iron, but the line of demarcation between the part not rusted and the rusty part is as well marked and defined as it was when the iron was first exposed. There is also in the black part of the coating a small spot of red crust, which appeared shortly after its exposure, which has not in the slightest degree enlarged. That the acid-vapors of a laboratory have not any action on this coating of magnetic oxide is proved by these specimens before you,

which for several months were kept in my laboratory where ten or twelve students are continually at work, and for six weeks of that time these pieces of iron were watered daily, except on Sundays, in order that the moisture might absorb the acid-vapors of the laboratory, and so corrode, if they could do so, the surface of the iron. You will notice that it is perfectly unchanged; but the places where the iron is exposed, through the intentional fracture of the iron, are all covered with red rust. Most of the specimens before you have been exposed for a longer or shorter time to the rain and dews of night, and I think you will see in all cases they have resisted more or less completely the action of the moist air. I need not take up your time longer by describing all the specimens before you, or by entering more fully into an explanation of the process. I believe I have already done it fully, and I believe in a way so simple that everyone, even the most unskilled in scientific matters, will be able to understand it.

Now, as regards its application to purposes in which you are all deeply interested. We will speak first about steam boilers and steam ships. Here is a piece of boiler plate, which after it was taken out of the furnace was rubbed with steel wire cloth and emery paper, which has produced this sort of gloss upon it. It has been some time in the sink of the laboratory, and is, as you will see, perfectly free from rust. The black coating is firmly adherent to the surfaces. Suppose a boiler plate or an armor plate to have its holes drilled and to be oxidized, and suppose also that the rivets are oxidized as well, then when the plates are riveted together, the rivets being heated till they become soft, a proper pressure is brought to bear upon them, and this pressure may possibly interfere with the coating on the head of the rivets. I don't see well how it can interfere with it upon any other part of them. Next comes the caulking: and here, no doubt the tools used would go through some of the black oxide and expose small portions of metallic iron, and this might rust. However, I must here mention that in one specimen before you, which I exhibited at the Society of Arts, a notch has been cut, and this was done by some

one at the meeting in order to test its hardness. Now, it has been exposed ever since to the action of moisture, and this notch as you will see, is not rusted at all, so that I fancy the iron is rendered non-rustable to a depth below the black surface, and this view is confirmed by the fact that almost every piece of iron from which I have removed the black surface only, without going into the iron below, has never rusted to any appreciable extent, and that the rust which forms upon it is not of the deep color of ordinary rust, but is yellow, like certain well known hydrates of the sesqui-oxide of iron, and that, moreover, this yellow substance can be wiped off, leaving the iron perfectly clean. This cannot be done to any piece of metal on which has been formed the ordinary iron rust. At present I am not in a position to speak with certainty, resulting from experiment, as to whether this process can be applied to ships or boilers, so as to prevent rust in every part. But even suppose we cannot get over the difficulty resulting from the disturbance of the coat of oxide on the rivet-heads, it seems to me that very much will be gained by our being able to render the plates non-rustible, for it is manifest that it would take a very long time for iron rust to eat vertically into the head of a rivet. But I am sanguine enough to believe that this difficulty, which is not nearly so great as others which have been overcome in the perfecting of this process, will be vanquished likewise. One of the specimens before you has been placed in salt and kept in a moist atmosphere where the salt was alternately dry and wet for a very long time, and you will perceive that this black coating has been in no way affected. I do not, therefore, think that there is any fear of sea-water decomposing it. This small sample of black oxide was taken from the sea-shore and it has never rusted. I think that we have been able to prove that gun-barrels can be treated with it without injuriously affecting their surface. You will see before you several specimens, and of the effect produced upon them you will be better judges than I am. Several officers in the Navy have mentioned other applications which will be of inestimable benefit to various portions in the structure and furniture of ships.

But here, again, Gentlemen, I need not take up your time by detailing them; for now you know the process thoroughly, you will be the best judges as to where it can be efficiently employed; for to all the bright iron and steel work in use among soldiers, whether helmets, swords, or scabbards, it may be applied with great advantage. For, as far as I know, it does not interfere with the strength or tenacity of the metal, and it most certainly hardens its surface. For stores of iron cannon balls and shells, its application will be of very great advantage. An officer in the American Army told me the other day that the rusting of these materials of war is a source of considerable inconvenience. It is rather for you, Gentlemen, to point out to me the ways in which it can be made of use to you, than for me to mention them to you, and then I conceive it is my business to practically carry out your views, and see whether its application is admissible. Some time ago Mr. Perkins read, as I hear, a most interesting paper here upon his boiler-tubes, in which he mentioned the strange results which had arisen from the action of water upon them at very high temperatures, and therefore under very considerable pressure. I am sorry to say that at present I am not able to throw that light upon the subject which I could wish to do, for a series of experiments which I am performing with specimens which he has given me are not yet completed. If by the time this paper is read I have completed them, I will write an account, which shall be appended to it. And thanking you very much for the kind attention you have given me, I shall now be happy to hear any remarks which you may desire to make, and to answer to the best of my power any question you may ask me.

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FOR experimentally illustrating the composition of light Mr. Wm. Terrill arranges seven lanterns, with glass slides stained to imitate the different colors of the spectrum. By turning the lanterns so that the projected circles overlap, a circle of white light is produced. Interesting experiments with complementary colors may be performed in the same way.

## DYNAMO-ELECTRIC APPARATUS.

From "Engineering."

It cannot but force itself upon the mind of any thinking person that among all the forces of nature, so many of which have already been called into use in the ever onward march of industrial progress, electricity is destined to take a very prominent place in the immediate future. Indeed, there are not a few indications to warrant the belief that the coming half century will be characterized in the world's history as an electrical age, just in the same way as previous periods have left their mark according to their several characteristics being referred to as "Golden Age," "the Age of Literature," "the Iron Age," and others to which special characteristics belong.

A retrospect of the last twenty, or even of the last ten, years is sufficient to show that electricity and its applications have had an important and rapidly increasing share in the inventions and the industries of the world. Electric telegraphy has been reduced to an exact science, and has given rise to a new and distinct profession—that of the telegraph engineer—besides giving employment to thousands in the manufacture of telegraph lines of submarine cables, and of signaling instruments. Another branch of it has rendered possible the safe and rapid facilities of transit which railway communication affords, for it would be idle to suppose that the railway system could ever have developed itself into anything like the power that it is had it not been aided by the electric telegraph.

Again the arts of electro-plating and of electro-typing have become large and important branches of industry, especially in this country and in France, the latter by the cheap and rapid facilities it affords for the reproduction of engravings having already revolutionized the production of illustrations for an important branch of literature.

The great novelty of the day, the telephone, has done much in a short time to draw popular attention to some of the most interesting capabilities of electricity, and has prepared the public mind to a very great extent for believing almost

anything of electricity and for taking up inventions and industries which are based upon electrical phenomena.

As long, however, as the only available sources of electricity were voltaic batteries, consuming as they did so expensive a fuel as metallic zinc, the applications upon a large scale of electrical action were very limited on account of its cost. The discovery by Faraday of magneto-electricity and the various magneto-electric machines which arose therefrom, appeared to open up a field in which cheap electricity might be sought, and by which several experiments hitherto confined to the laboratory might become developed into branches of industry. The machines of Holmes and of the Société l'Alliance were the first applications upon a large scale of Faraday's discovery, and the illumination of several of the important lighthouses on the coasts of England and France by the electric light generated by the Holmes machine and by its French modification, the Alliance machine, gave a fresh impetus to electrical progress.

In both these machines, however, the current was induced from permanent steel magnets which could not retain sufficient magnetism to maintain a magnetic field of sufficient intensity to induce powerful electrical currents in the coiled armatures. To compensate for this deficiency, the number of magnets and of armatures had to be multiplied, and the size of the machines as well; their cost for driving (to say nothing of prime cost) was thus very great. The Siemens cylindrical armature utilized to the best advantage the inductive action of the magnets. As long, however, as the induction of electrical currents was produced by the action of permanent magnets, an increase in the size of a machine did not produce a proportional increase of results, and as it was found that iron takes an appreciable time to be magnetized and to be demagnetized, there was also a limit to the speed at which a machine could be driven so as to produce satisfactory results.

Mr. Wilde, by employing electro-magnets (excited by a smaller magneto-electric machine) for inducing the currents in a Siemens armature, supplied the connecting link between the early magneto-electric and the modern powerful dynamo machines, which depend for their action upon what is called the action and reaction principle of magnetization, which has been rendered familiar to the readers of this journal by a recent correspondence carried on in these columns relative to the question of priority of its discovery. It is the employment of this mutual action that distinguishes dynamo-electric from magneto-electric machines, and it carries with it this overwhelming advantage that the power of a dynamo machine increases in proportion to its size, to which practically there is no limit.

There are at the present time but two dynamo-electric machines of sufficient development to be considered in this article, viz., the Gramme and the Siemens machines, both of which have been described in these columns. The former has now become a very formidable rival in France to the Alliance machines for the production of the electric light, and has recently been employed during the building of the Paris Exhibition for enabling the building operations to be carried on at night.

The Siemens machine has, however, carried off the palm in all competitive trials with the Gramme, and in an article in our last volume we embodied the results of a long series of most interesting experiments made for the Corporation of the Trinity House by Dr. Tyndall and Mr. J. N. Douglass, for ascertaining the comparative merits of the two machines. From these experiments (a detailed account of which was given in the reports of Dr. Tyndall and of Mr. Douglass which we printed in the same volume) it was proved that to produce the same light a Siemens machine would weigh 3 cwt. as against 25 cwt. for Gramme, and would require to drive it but 3.3 horse power against 5.5 for Gramme, giving a proportion of light produced per horse power of 2080 for Siemens to 1257 for Gramme. Thus one Gramme machine would weigh more than eight Siemens machines of equal power, its cost of driving would be

nearly double, and in addition to these points in favor of the Siemens machine, the prime cost of the machine is as 100 for Siemens to 320 for Gramme, that is to say that three Siemens machines cost less than one Gramme machine of equal illuminating power. We are told in a letter from Mr. Charles Ball, which appeared in our issue of the 2nd of November last, that the Gramme machine has been improved since the Trinity House experiments were made, but as that improved machine has never been subjected to any recognized competitive trial against the Siemens machine, the necessary data are wanting for estimating the relative merits of the two machines.

Whatever form, however, will ultimately prevail, it is to dynamo-electric apparatus that we must look for bringing about that great future for electricity which has often been predicted in these columns, and we are glad to see that the importance of the subject is being recognized at head-quarters, and we must congratulate the Institution of Civil Engineers upon the valuable paper upon dynamo-electric apparatus by Dr. Paget Higgs and Mr. Brittle, which was read at the meeting last week, and which gave rise to a very interesting discussion which is not yet closed. In the paper, of which we published a short abstract in our last issue, the authors, after reviewing the history of the subject, gave a full description of the latest improvements of the Siemens machine, and of the special apparatus designed by Messrs. Siemens for the new electric lights at the Lizard lighthouses.

In connection with electric illumination it is not possible to overrate the importance of the lamp or regulator, by which the carbons are maintained at such a distance apart as to insure a steady light. Hitherto it has always been a weak point in the application of electricity to illumination purposes that the light produced was of an unsteady and flickering nature. This fluctuation might be produced by one or more of three causes: (1) variations in the speed of the machine, whereby the electro-motive force was rendered inconstant; (2) defects in construction of the regulator; and (3) impurities and want of homogeneity in the carbon points. The first of these is a simple mechanical question

and can be remedied by an efficient governor to the engine. The second has been got over in the lamp of Messrs. Siemens, which, while quickly adapting itself to variations in the current is exceedingly simple and not liable to be come deranged as are the highly complicated clockwork regulators of Serrin, Foucault, Duboscq, and others. Uniformity in carbons can only be secured by careful selection, but during the last few years the manufacture of carbons for electrical purposes has greatly improved, and only wants the stimulus of a large demand to induce manufacturers to pay the attention to it that the importance of the subject deserves. The presence of small granules of silica seems to be the most deleterious, causing portions of the carbon points to split off often with a slight explosion. The plan of electro-plating the carbons with a thin film of metallic copper is one which recommends itself for several reasons. It gives to the carbon sticks a uniform conductivity and diminishes their resistance, by which they are kept from being heated by the passage of the current, and by encasing them in a copper sheath it reduces to a minimum their chances of splitting, besides making them less fragile to handle, and the film of copper is so thin as not to affect the color of the light by its own vaporization or to produce noxious sublimates in the atmosphere in which the lamp is burning.

If, while a dynamo-electric machine is running, its terminals be connected together, its external circuit being thereby closed, it will be found that a great resistance is offered to the rotation of the machine; the closing of the external circuit has an effect upon the engine similar to that produced by suddenly putting a heavy cut upon a lathe, and were it not provided with an efficient governor, the engine would, to a certain extent, be pulled up. Similarly if, while the machine is running, the external circuit be broken, work is taken off the machine, and without a governor the engine would "run away." From this it will be apparent that if the lamp were suddenly put out, the load would be taken off the engine, and injury might accrue from the suddenly increased speed of rotation. To remedy this a self-acting

shunt is interposed between the machine and the lamp.

In the paper read before the Institution of Civil Engineers some very interesting comparisons were given between the cost of lighting by electricity and of lighting by gas, the proportions of which vary greatly in different places, being dependent upon the cost of gas at the particular place selected, and upon the kind of motive power employed to drive the machines. It appears, however, that for the illumination of large areas the cost of the electric light is about one-fourth or one-fifth of that of lighting by gas. At the works of Messrs. Siemens Brothers it has been found that there the economy is as two to one in favor of the electric light over gas, with the further advantage that the lighting is perfect, and is not attended with the inconvenience that gas is subject to, of being obscured by steam or fog.

We cannot doubt that the time will come when central stations for distributing electric power will be established in all our large towns for illumination purposes, for the transmission of power to a distance, and for other manufacturing and industrial purposes. There are abundant data by which it can be shown that coal can be more economically used for the illumination of a town by being consumed in a steam engine, which is employed to drive a set of dynamo-electric machines, than by being converted into gas and conveyed by pipes all over the district to be lighted. Again, for the transmission of power from a central station, where strict economy can be practiced, aided by very perfect steam engines, economical results would be obtained, for the great waste of energy caused by a number of small and badly constructed steam engines, would more than cover the extra cost of transmission by means of electricity, from a center where economy was practiced upon sound scientific principles.

A method of illuminating large halls was exhibited to the meeting during the discussion on the paper above referred to. This arrangement, which was first suggested to Dr. Siemens by the Duke of Sutherland, consists in projecting the rays from an electric lamp by means of a concave reflector vertically upwards

upon a white ceiling, or, as was done at the Institution, upon a large white sheet, stretched horizontally across the roof. The effect was as near to perfection as illumination could be: the reflector being deep enough to screen direct rays of the lamp from the eyes of the audience there was no unpleasant glare, and the room was flooded with a soft, purely white, and at the same time most brilliant light, so perfectly distributed that it was impossible to cast a shadow upon a

sheet of paper by an object placed twelve inches off. The most striking effect, however, was produced by the electric light being stopped, leaving the three powerful "sunlights" doing their work alone.

The effect was as if the whole room was suddenly enveloped in a thick yellow fog, and it was difficult to believe that the illumination was the same as what appeared so brilliant before the electric light was shown.

## PROGRESS OF TELEGRAPH ENGINEERING.\*

By DR. C. W. SIEMENS.

From "Journal of the Society of Arts."

IN reviewing the progress made in telegraph engineering during the last few years, I propose to notice in the first instance the subject of duplex and quadruplex telegraphy, which has recently much occupied the attention of the telegraph engineer. Duplex telegraphy has been known and practiced to a very limited extent since 1854 (?) when it was first announced by C. A. Nystrom, of Oreboro, Sweden, and by Dr. Gintl, of Vienna, and carried out practically by Frischen and Dr. Werner Siemens. Although quite successful in some of the applications made at that time in Germany, in Holland (between Amsterdam and Rotterdam), and in this country, under my own superintendence, between Manchester and Bowden, telegraphy itself had not advanced sufficiently to call for an application of this invention upon a more extended scale, and it has only met with favor on the part of telegraph administrators since its reintroduction to public notice by Mr. Stearn, of Boston, in 1872, who improved, however, upon the original arrangement by balancing the discharge from the line by the discharge from an arrangement of condensers. Another important advance in duplex telegraphy has been made by Mr. Louis Schwendler, who, by the application of an improved Wheatstone bridge arrangement has produced the means of

readily adjusting the effect of the neutralizing current during the working of the instrument, and has carried duplex telegraphy into effect with great advantage upon the long lines of India, with which he is connected.

The quadruplex telegraph, which may be considered to have been theoretically introduced by Dr. Stark of Vienna in 1855, and contemporaneously by Dr. Boscha of Leyden, has been developed by Mr. Edison of New Jersey, United States, and has been for some time established upon the line between New York and Boston, under the superintendence of Mr. Prescott, the engineer of the Western Union Line. In this system the principle of duplex telegraphy is combined with the equally well-known system of producing different effects by currents differing in strength.

Our attention is next arrested by the great novelty of the day, the telephone. This remarkable instrument owes its origin to the labors of several inventors. In the year 1859 the late Sir Charles Wheatstone devised an arrangement by which the sounds of a reed or tuning-fork, or a combination of them, could be conveyed to a distance by means of an electric circuit, including at both stations a powerful electro-magnet. In striking any one of the tuning forks differential currents were set up which caused the vibration of the corresponding tuning fork at the distant station, and thus com-

\* Presidential Address delivered at the Annual Meeting of the Society of Telegraph Engineers, January 23d 1878.

municated the original sound. In 1861 Reiss enlarged upon this ingenious suggestion in attempting to convey the varying vibrations of a diaphragm agitated by atmospheric sound-waves. This instrument transmitted currents only of equal intensity, and produced therefore sounds of equal calibre, distinguishable only by their periods. Mr. Edison, by establishing contacts through the medium of powdered plumbago, has succeeded in transmitting galvanic currents varying in intensity with the amount of vibration of the diaphragm. As another step towards the accomplishment of the perfect transmission of sound, I should mention also the logograph, or recorder of the human voice, which Mr. William Henry Barlow, F.R.S., a member of our society, communicated in a paper to the Royal Society, on the 23d February, 1874.

The beautifully simple instrument of Professor Graham Bell, of Cambridge, United States, must be regarded as a vast step in advance of all previous attempts in the same direction. In making the diaphragm of iron, and having recourse to Faraday's great discovery of magneto-induction, Mr. Bell has been able to dispense with the complication of electrical contacts and batteries, and to cause the vibrations of the diaphragm imparted by the voice to be accurately represented in strength and duration by electrical currents, thus producing the marvelous results of setting up analogous vibrations in the diaphragm of the receiving instrument, which, though weaker than the vibrations imparted to the transmitting diaphragm, so closely resemble them as to repeat the quality of voice which causes the original vibrations. The currents transmitted are so minute as to escape observation by the most delicate galvanometer, as the magnetic needle, however light, must be too sluggish to be moved visibly by such quick impulses, and it requires an electro-dynamometer of exceeding sensitiveness to bring them into evidence. The rapidity with which these reversing currents follow each other can be accurately determined in transmitting the sound of a high-pitched tuning fork, and Mr. Kötngen concludes, from experiments he has made in this direction that not less than 24,000 currents can be transmitted in one second. The system of suspended

line-wires now generally in use is open to many grave objections. The mutual induction between parallel line-wires, and the leakage from one wire to another through the supporting poles are a permanent source of trouble in working telegraph instruments. Again, it happens that not unfrequently suspended line-wires are thrown down, causing the almost entire cessation of telegraphic communication for days in the event of a great gale or snow-storm. The remedy for these interruptions is undoubtedly the underground line-wire system. This was first tried in Germany upon an extended scale in 1848-9, but was given up in favor of the suspended line in consequence of the want of experience in manufacture and imperfect protection afforded to the gutta-percha-covered copper wire. Since then it has been largely used in this country. The German Telegraph Administration, under the able direction of Dr. Stephan, has within the last year or two again resorted to the application of the underground conductor for long lines. A representative cable of what it was intended to lay was put down in 1876 between Berlin and Halle, a distance of 120 English statute miles. The success of this line induced his Government to lay down last year multiple cables between Berlin and Cologne, and Berlin, Hamburg, and Kiel, an aggregate distance of 600 miles, while further extensions are in course of execution.

In submarine telegraphy no startling feat of novelty can be reported, although steady progress has recently been made in improving the manufacture of the insulated conductor, in the attainment of an increased rate of transmission through long distances, in the outer protection given to the insulated conductor, and in the vessels and other appliances employed for submerging and repairing deep-sea cables. The conductor almost universally adopted in the construction of submarine cables has been a strand of seven copper wires, covered with three thicknesses of gutta-percha, with intervening layers of a fusible resinous compound.

In the case of the Direct United States Telegraph Company's Cable, the conductor consists of one large central wire of 0.090 inches diameter, surrounded by

eleven small copper wires of 0.035 inches diameter.

Although this country has from the first taken a prominent part in the invention and development of the electric telegraph, and is still the seat of oceanic telegraphic enterprise, almost to the exclusion of other countries, it has lately been asserted that other countries, and especially the United States, are now taking the lead in telegraphic improvement, and it behoves us to inquire whether such an allegation is founded on fact, and, if so, whether it is attributable to indolence on our part or to circumstances beyond our control. It cannot be denied that the more startling innovations of recent days have chiefly emanated from the United States, the only civilized country in which, as it happens, internal telegraph communication is still in the hands of private companies. Is it, it may be asked, this open competition which has stimulated the American inventor to bring forth duplex and quadruplex telegraphy, the telephone, and other innovations? I incline to the belief that the open competition for public favor does act as a powerful stimulant to invention in the United States, a stimulant which was equally active in this country in producing a variety of novel instruments, at the time prior to the purchase of the telegraphs by the Government. In frankly giving expression to this opinion, I do not mean to call in question the wisdom of the policy which dictated the purchase, on public grounds, of the telegraphs by Government. Through it we have obtained a uniform and moderate tariff, an extension of the telegraph system to minor stations (although the number of stations open in this country does not yet exceed that provided in the United States, being in the one case a station for every 5,607, and in the other for every 5,494 inhabitants), and a better guarantee for the secrecy of messages.

It is a question worthy of consideration whether the Acts of Parliament of 1868-9, by which the Government Department of Telegraphs was created in this country, do not go beyond the limits necessary to insure a well-regulated public service in taking the construction, as well as the working of the lines, out of the hands of public enter-

prise. They give, for instance, to the department the faculty of purchasing letters patent, whereby an interest is created in favor of particular instruments, to the prejudice of others of perhaps equal merit, and such a course is by no means calculated to stimulate invention.

The erection of lines for local and private purposes is an important branch of telegraphy which I submit should have remained entirely outside the scope of a public department, in order that competition might have a free opportunity of developing such applications, as is the case in the United States, where private and circular telegraphy is undoubtedly in advance of other countries. Great improvements have indeed been recently made by the Postal Telegraph Department in the rate of working of Wheatstone's automatic circuits, and in the employment of fast-speed translators or repeaters, as is proved by the following data, for which I am indebted to our vice-president, Mr. W. H. Preece. It has been found that the insertion of one of the new fast-speed translators in Dublin has more than doubled the rate of working between London and Cork, and the insertion of one of these relays in Anglesea has improved the rate of working between London and Dublin about fifty per cent. As an indication of the rate at which messages can be transmitted, it appears that the Queen's Speech, containing 801 words, was sent to Leicester in 4 minutes 28 seconds, being at the rate of 179 words per minute. The quickest rate at which it was sent by key was between London and Reading, where it occupied 17 minutes, or at the very high speed of 47.1 words per minute. It is, perhaps, interesting to remark that on the first night of the session over 420,000 words were actually transmitted from the central station, and over 1,000,000 words were delivered in different parts of the country.

The quadruplex system of telegraphy continues to be worked with very satisfactory results between London and Liverpool, and it has quite quadrupled the power of the one wire to carry messages. The highest number of messages transmitted in one hour has been 232; about 200 per hour have frequently been

sent. The system of duplexing Wheatstone automatic circuits is gradually extending, and on the Leicester wire which carried the Queen's Speech, at the rate named, messages were being transmitted in the opposite direction by the duplex arrangement at the same time. In submarine telegraphy ample scope still exists, as I have endeavored to show, for the ingenuity and enterprise of the telegraph engineer; but here again the free exercise of these faculties is threatened, not by legislative action, but by a powerful financial combination. It is intended by this combination to merge the interests of all oceanic and international lines and the construction of new lines into one interest.

Electricity has hitherto rendered service as the swift agency by which our thoughts are flashed to great distances, but it is gradually asserting its rights also as a means of accomplishing results where the exertion of quantitative effects are required. Much has been said about the application of electricity for producing light, and the French Company Alliance, as well as the Gramme Company, have it is known for some years been establishing magneto-electric apparatus to illuminate the lighthouses upon the French coast, and for galvanoplastic purposes. By an ingenious combination of two magneto-electric machines, with Siemens armatures, Mr. Wilde, of Manchester, succeeded in greatly augmenting the effects produced by purely mechanical means, but the greatest impulse in this direction was given in 1866-67 by the introduction of the dynamo-electrical principle, which enables us to accumulate the current active in the electric circuit to the utmost extent permissible by the conductive capacity of the wire employed. Dr. Tyndall and Mr. Douglas, chief engineer to the Trinity Board, in reporting lately to the Elder Brethren upon the power of these machines and their applicability to lighthouses, give a table showing that a machine weighing not more than 3 cwt. is capable of producing a light equal to 1,250-candle power per horse-power expenditure of mechanical energy. Assuming that each horse-power is maintained with an expenditure of 3 lbs. of coal per hour (which is an excessive estimate), it would appear that

1 lb. of coal suffices to maintain a light equal to  $417\frac{1}{2}$  normal candles for one hour. The same amount of light would be produced by 139 cubic feet of gas of 18-candle power, for the production of which 30 lbs. of coal are consumed. Assuming that of this quantity, after heating the retorts, &c., 50 per cent. is returned in the form of gas-coke, there remains a net expenditure of 15 lbs. of coal in the case of gas-lighting to produce the effect of 1 lb. of fuel expended in electric lighting, or a ratio of 15 to 1 in favor of the latter. Add to the advantages of cheapness in maintenance, and of a reduced capital expenditure in favor of the electric light, those of its great superiority in quality and its freedom from the deleterious effects of gas in heating and polluting the atmosphere in which it burns, and it seems not improbable that it will supersede before long its competitor in many of its applications. For lighthouses, for military purposes, and for the illumination of large works and public buildings, the electric light has already made steady progress, while for domestic applications the electric candle proposed by Jablikoff, or modifications of the same, are likely to solve the difficulty of moderating and distributing the intense light produced by the ordinary electric lamp.

The dynamo-electric machine has also been applied with considerable success to metallurgical processes, such as the precipitation of copper in what is termed the wet process of smelting. The effect of 1 horse-power expended in driving a dynamo-electric machine of suitable construction is to precipitate 1120 lbs. of copper per twenty-four hours, equivalent to an expenditure of 72 lbs. of coal, taking a consumption of 3 lbs. of coal per horse-power per hour. Electrolytic action for the separation of metals need not be confined, however, to aqueous solutions, but will take perhaps an equally important development for the separation in a state of fusion of the lighter metals, such as aluminium, calcium, and of some of the rarer metals, such as potassium, sodium, &c., from their compounds. Enough has been shown by Professor Himly, of Kiel, and others, to prove what can be done in this direction. In an inaugural address which I had occasion to deliver to the

Iron and Steel Institute, a twelvemonth ago, I called attention to another application of the dynamo-electric current, that of conveying mechanical power, especially the power of such natural sources as waterfalls, to distant places, where such power may find useful application. Experiments have since been made with a view to ascertain the percentage of power that may thus be utilized at a distance, and the results of these experiments are decidedly favorable for such an application of the electrical conductor. A small machine, weighing 3 cwt., and entirely self-contained, was found to exert 2.3 horse-power as measured by Prony's brake, with an expenditure of 5 horse-power at the other end of the electric conductor, thus proving that above 40 per cent. of the power expended at the distant place may be recovered; the 60 per cent. lost in transmission includes the friction of both the dynamo-electric and electro-motive engines, the resistance of the conductor, and the loss of power sustained in effecting the double conversion.

Without considering at present the utilization of natural forces, let us take the case of simply distributing the power of a steam-engine of say 100 horse-power to twenty stations, within a circle of a diameter, for the production of both light and power. The power of 100 horses can be produced with an expenditure of 250 lbs. of coal per hour, if the engine is constructed upon economical principles, or of

$$\frac{250}{20} = 12.5 \text{ lbs.}$$

per station. In the case of the current being utilized for the production of light

$$2.3 \times 1200 = 2760,$$

or, say, 2,000 candle power, are producible at the station, whereas, if power is desired, 2.3 horse-power may be obtained, in both cases with the expenditure of 12.5 lbs. of coal, representing a penny an hour for cost of fuel, taken at 15s. a ton. The size of the conductor necessary to convey the effect produced at each station need not exceed half an inch in external diameter, and its cost of establishment and maintenance would be small as compared with that of gas or

water pipes for the conveyance of the same amount of power.

Electricity, which in the days of Franklin, Galvani, Volta, and Le Sage, was regarded as an ingenious plaything for speculative minds, and did not advance materially from that position in the time of Oersted and Ampère of Gauss, and Weber, and not indeed until the noonday of our immortal Faraday, has, in our own times, grown to be the swift messenger by which our thoughts can be flashed either overland or through the depths of the sea to distances circumscribed only by terrestrial limits. It is known to be capable of transmitting, not only language expressed in conventional cypher, but facsimile copies of our drawings and hand writing, and at the present day even the sounds of our voices, and of resuscitating the same from mechanical records long after the speaker has passed away. In the arts it has already played an important part through the creation by Jacobi of the galvano-plastic process, and in further extension of the same principle it is rapidly becoming an important agent in the carrying out of metallurgical processes upon a large scale. It has now appeared as the formidable rival of gas and oil for the production of light, and, unlike those inferior agents, it asserts its higher nature in rivalling solar light for the production of photographic images; and, finally, it enters the ranks as a rival of the steam-engine for the transmission and utilization of mechanical power. Who could doubt, under these circumstances, that there remains an ample field for the exercise of the ingenuity and enterprise of the members of that society I have just had the honor of addressing?

THE prizes of the Paris Academy of Sciences have been recently awarded. Practical engineering has secured some of the important awards. In mechanics the Poncelet prize was awarded to M. Laguerre for his mathematical works; the Montyon prize to M. Caspari, for his work on chronometers; the Phumey prize to M. Fremenville, for his improvements in steam engines; the Fournayron prize to M. Mallet, for his tramway engine.

—*The Engineer.*

## ON THE EFFECTS OF PHOSPHORUS AND MANGANESE ON THE MECHANICAL PROPERTIES OF STEEL.

By M. EUVERTE.

From "Bulletin de la Société de l'Industrie minière," Abstracts published for the Institution of Civil Engineers.

In the year 1874, the Author made a communication to the Société des Ingénieurs civils, of Paris, on the manufacture, at Terre-Noire, of cast steel containing phosphorus. In this communication the general law was put forward that phosphorus might be introduced into steel, on the condition that the proportion of carbon contained in it was diminished; and that the less carbon the steel contained, the more phosphorus might be admitted into it without depriving it of its valuable properties.

The maximum proportion of phosphorus that may be introduced into steel, for rails, is from 0.28 to 0.32 per cent., on the condition that the amount of carbon contained at the same time in the metal does not exceed 0.18 to 0.22 per cent. Any excess of phosphorus beyond this limit renders the metal brittle, liable to be red-short and difficult to roll.

The Author then discusses the relative advantage of the Bessemer and the Siemens-Martin processes, for the production of steel from materials containing a sensible proportion of phosphorus; and, after having given a general preference to the latter, remarks that in making steel by it from scrap iron of any kind, more particularly from old rails, it is important, in the first place, to classify the scrap to be used, according to the amount of phosphorus in it;

as the proportion contained in iron rails varies from 0.15 to 0.80 per cent., and only so much of each quality may be used that the percentage in the steel produced shall not exceed 0.30 per cent.

The bed of the furnace, when used for making steel from old rails, is formed of silicious sand in the usual way. The materials to be melted are heated in an auxiliary furnace, before charging them into the melting furnace, to economize the heat of the latter, to admit of maintaining a more regular temperature in it, and to increase the rapidity of working.

The pig iron employed to form a bath may, if sufficiently pure, be of any quality, from the very greyest metal, containing 5 per cent. of carbon and 2 per cent. of silicon, to white iron containing 2.8 per cent. of carbon and no silicon. In the former case, the weight of pig iron required will be less than 10 per cent. of the total charge; in the latter it will be from 30 to 35 per cent. Where white pig iron, sufficiently free from phosphorus, can be obtained at a moderate price, it is advantageous to use this rather than gray iron; taking care, however, to avoid such metal as contains an excessive amount of sulphur. The white pig iron (*fonte blanche chaude*) of Solenzara has been that most used at Terre-Noire.

The following may be taken as the composition of a typical charge:—

	Weight Charged.	Percentage of Phosphorus.	Total Weight of Phosphorus in the Charge.
	Kilogrammes.		Kilogrammes.
White Solenzara pig iron.....	1,750	0.100	1.750
Light Steel scrap.....	800	0.100	0.800
Old iron rails, Creusot.....	850	0.700	5.950
“ “ Commentry, Fourchambault....	500	0.420	2.100
“ “ Loire.....	2,000	0.170	3.400
60 per cent. ferromanganese.....	140	0.270	0.378
Totals.....	6,040	—	14.378

The pig iron is first melted and raised to a high temperature, and the other materials, having been previously heated in the auxiliary furnace, are charged into

the bath, in quantities of from 4 to 6 cwt., and at intervals of fifteen to twenty minutes. The steel scrap is added first and then the old rails, beginning with those that contain the most phosphorus; as the total quantity to be put in is never quite fixed, it being necessary to add more or less according to the rate at which the oxidation of the metal goes on, and thus it is best to retain to the last that portion of the charge which will least affect the composition of the bath. As soon as so much scrap has been added that the metal begins to become malleable, test pieces are frequently taken from it and beaten out under a small steam hammer into plates 4 to 4½ inches in diameter and about ¾ inch thick. The earlier tests, taken while the metal is still hard, forge fairly well under the hammer, but are brittle when cold. As the process goes on, the test pieces become more and more red-short, but softer and more pliable when cold. When the last test is soft enough when cold to bend double without breaking, and shows a fibrous fracture, the ferromanganese, previously heated, is added at once, and the metal is tapped as rapidly as possible.

The time occupied in working a charge including the repair of the furnace, is from seven to eight hours, and the average output, per furnace, is 17½ to 18 tons in twenty-four hours. The loss is 6 to 8 per cent., and as there is no elimination of phosphorus in the process, the total quantity contained in the materials treated is concentrated in the steel; so that this will contain, in the case of the charge under consideration, 0.253 per cent., the mean percentage in the

metal charged being 0.237 per cent. The 140 kilogrammes of ferromanganese added contain 84 kilogrammes of metallic manganese, equal to 1.4 per cent. of the weight of the charge. This is an average proportion, but when the metal is much oxidized, as much as 2 per cent. more of manganese may be required; and good charges have on the other hand been made, under favorable conditions, with the addition of only 1 per cent. of manganese.

The manganese added is equal to 1.49 per cent. of the 5,650 kilogrammes of steel produced. Of this from 0.650 to 0.950 per cent. is found by analysis to be contained in the metal, the rest passing into the slag.

The metal, before the addition of ferromanganese, contains from 0.11 to 0.12 per cent. of carbon; and as the ferromanganese itself contains 5.50 to 5.75 per cent., the total quantity of carbon in the steel, if none were burned out, should be from 0.245 to 0.265 per cent. The amount found in it is from 0.220 to 0.260 per cent.

The mechanical properties of steels containing phosphorus, made as above described, depend to a great extent, not only on the amounts of carbon and phosphorus that they contain, but also on the proportion of manganese introduced into them.

The following table shows the average deflections, under successive increments of load, of steel rails containing different percentages of carbon, phosphorus, and manganese. The rails were of flange section, 60 lbs. per yard, and rested on supports 1 meter apart. The deflections are given in millimeters.

Load (in Tons of 1,000 Kils).	C=0.45-0.55 P=traces. Mn=0.15-0.25		C=0.15-0.20 P=0.27-0.32 Mn=0.25-0.35		C=0.17-0.22 P=0.28-0.31 Mn=0.50-0.70		C=0.17-0.22 P=0.25-0.77 Mn=1.00-1.20	
	Deflection.		Deflection.		Deflection.		Deflection.	
	Under Load.	Permanent.	Under Load.	Permanent.	Under Load.	Permanent.	Under Load.	Permanent.
12.5 tons.....	2.5	0.0	2.3	0.0	1.9	0.0	1.8	0.0
17.5 ".....	3.2	0.0	3.0	0.0	2.3	0.0	2.3	0.0
20 ".....	3.5	0.0	3.4	0.0	2.8	0.0	2.7	0.0
25 ".....	4.4	0.2	4.4	0.1	3.6	0.1	3.5	0.2
30 ".....	8.3	3.2	23.8	18.7	12.6	8.3	9.4	5.1
35 ".....	16.3	10.0	38.7	31.5	33.8	28.5	23.9	18.8
Load causing fracture	45 to 49 tons.		43 to 48 tons.		43 to 48 tons.		43 to 48 tons.	

The behaviour of the four varieties is thus almost identical up to the limit of elasticity; beyond that point, the deflection of the phosphoretted metal is much greater than that of the rail made of Bessemer steel of ordinary quality; but by augmenting the proportion of manganese, the strength and stiffness of the former are increased. The results of tests of the same rails by a falling weight correspond to those of the dead-weight tests; the rails that contain more manganese being stiffer and stronger than those containing less; the rails of phosphoretted metal that contain 1 per cent. of manganese, or more bearing even a heavier blow, without fracture, than rails of ordinary good Bessemer steel, nearly free from phosphorus.

Other tests show that the strength and ductility of phosphoretted steel are increased, much more than is the case with ordinary steel, by casting the ingots

large, and putting as much mechanical work on the metal as possible; and that when the phosphoretted steel has been submitted to sufficient working, it has, for metal giving an equal percentage of elongation, a greater tensile strength than steel free from phosphorus. It is probable, also, that the employment of more powerful machinery, rendering it practicable to cast phosphoretted steel in larger ingots, and to put more work on it, will permit of making good rails from metal containing more than the present limit of 0.3 per cent. of phosphorus.

The effect of an increased percentage of manganese, on steels containing but little phosphorus, is to augment the strength and the ductility of the metal to a remarkable degree, as shown by the following table of the properties of varieties of Bessemer metal containing different proportions of manganese:

	No. 1. C=0.65-0.80 P=0.03-0.05 Mn=0.12-0.15	No. 2. C=0.22-0.35 P=0.03-0.05 Mn=0.12-0.15	No. 3. C=0.35-0.45 P=0.06-0.08 Mn=0.95-1.05
Limit of elasticity (tons per square inch)...	21.59	16.00	23.84
Breaking load.....	38.10	29.60	43.61
Elongation % (on test pieces 4 inches long)*	5.00	21.40	21.28

The steel containing about 1 per cent. of manganese has thus a tensile strength greater than that of the harder ordinary steel, No. 1, coupled with a ductility nearly equal to that of the softer and weaker metal, No. 2.

Another property of manganese, when alloyed with steel, is to augment the extent to which it is capable of being hardened or tempered, when heated to redness and cooled rapidly. This may be seen from the following comparison of the properties, in the untempered and tempered states, of steels containing re-

spectively 0.25 to 0.30, and 0.35 to 0.45 per cent. of carbon, together with different proportions of manganese:

(See Table on following page.)

Steel containing phosphorus as well as manganese extends less, before breaking, than steel containing the same amount of manganese together with little or no phosphorus, while it has about the same ultimate tensile strength; and it is also less affected by tempering. Thus steel containing C=0.35 to 0.45, P=0.24 to 0.27, and Mn=1.15 to 1.25 per cent., gives the following results:

	Untempered.	Tempered in Oil, from dull Redness.
Limit of elasticity (tons per square inch).....	22.18	19.90
Breaking load.....	42.96	49.14
Elongation per cent. (on test pieces four inches long).....	17.25	9.75

\* The ordinary size of the test pieces in use at Terre-Noire is 3.93 inches (10 centimeters) in length by 0.59 inch (15 millimeters) in diameter.

	C=0.25-0.30 P=0.06-0.10 Mn=0.35-0.45		C=0.25-0.30 P=0.08-0.10 Mn=0.50-0.60		C=0.35-0.45 P=0.06-0.08 Mn=0.50-0.60		C=0.35-0.45 P=0.06-0.08 Mn=0.95-1.05	
	Untempered.	Tempered in Oil, from dull Redness.	Untempered.	Tempered in Oil, from dull Redness.	Untempered.	Tempered in Oil, from dull Redness.	Untempered.	Tempered in Oil, from dull Redness.
Limit of elasticity(tons pr. sq. inch)....	15.98	21.97	17.71	20.857	19.60	22.85	23.83	19.57
Breaking load (tons per sq. inch).....	30.00	39.05	34.99	41.97	36.69	42.85	43.81	53.33
Elongation % (on test pieces 4 inches long)	26.75	21.00	27.00	9.50	23.00	9.80	21.28	1.25

This is a considerably less degree of hardening than that shown by steel containing the same proportion of carbon and only 0.95 to 1.05 per cent. of manganese, together with little phosphorus.

An excess of manganese, while it increases the strength of steel, may at the same time (if carbon is also present in sensible quantity) render it brittle.

## THE BRITISH BOARD OF TRADE AND CONTINUOUS BRAKES.

From "The Engineer."

THE Railway Department of the Board of Trade is never weary of urging on the railway companies of Great Britain the necessity for using continuous brakes. It is much to be regretted that certain companies appear to have obstinately determined that they will either adopt nothing of the kind until its use is forced upon them, or to retain in their service systems of so-called continuous brakes which have been proved over and over again to be untrustworthy. A correspondence which has recently taken place between the Board of Trade and the railway companies—just published—bears very instructively on this matter. It will be remembered that a correspondence took place last year between the Railway Companies' Association and the Board on the subject of continuous brakes, to which we have already referred at length. A second circular, issued on the 30th of August, 1877, calls the attention of the companies to that correspondence, and states that the Board has been giving further attention to the subject, and from a careful examination of the reports of its officers on the acci-

dents which have occurred during the last few years, the Board has arrived at the conclusion "that three-fourths of these accidents might be avoided, or the results materially mitigated, if the passenger trains concerned had been fitted with continuous brakes." The circular then goes on to point out how desirable it is that a uniform system of brake should be used, at least by all companies working over each other's lines. Thus "the London and North Western, the Great Northern, and the Midland Companies all run through trains to Scotland, which are forwarded over the Caledonian, North Eastern, North British, Glasgow and South Western, and Highland railways. It is, therefore, obvious that the advantage to be derived from any continuous brake system in use on any of these lines will be diminished and neutralized, if at such stations as Carlisle, Glasgow, York, Edinburgh, Perth, and Inverness, the traffic is so arranged that carriages with one system of brakes are attached to trains containing carriages fitted with a different system. The evil can only be avoided if those companies

which interchange traffic with one another adopt one and the same general system." The Board adds with regret that it fails to find any evidence of an intention on the part of the different companies to take any steps towards this end. The circular is especially hard on the Clark and Webb brake, used on the London and North Western Railway, and which "No other great company has ever tried." After referring to the adoption of the Westinghouse and vacuum brakes by other companies, the circular goes on to say:—"Under these circumstances the Board of Trade, whilst recognizing the efforts which some of the companies are making in testing or adopting improved systems of brakes, cannot regard the state of things shown by these papers as satisfactory, inasmuch as it indicates a diversity of opinion and action, and in some cases an absence of progress, which, if allowed to continue, will be most injurious to the character of the companies and to the interests of the public. There has apparently been no attempt on the part of the various companies to take the first step of agreeing upon what are the requirements which in their opinion are essential to a good continuous brake. In the opinion of the Board of Trade these conditions should be as follows:—(a) The brakes to be efficient in stopping trains, instantaneous in their action, and capable of being applied without difficulty by engine-drivers or guards. (b) In case of accident to be instantaneously self-acting. (c) The brakes to be put on and taken off (with facility) on the engine and every vehicle of a train. (d) The brakes to be regularly used in daily working. (e) The materials employed to be of a durable character, so as to be easily maintained and kept in order. The inquiries and experiments instituted by the Royal Commission on Railway Accidents, and the recent researches into the causes of railway accidents during the last few years, appear to the Board of Trade to leave no doubt as to the importance of the above conditions, and the experience which has been obtained by the companies appears sufficient to enable them to come to some general and unanimous conclusion. There can, therefore, be no reason for further delay, and the Board of Trade feel it their duty again to urge upon the rail-

way companies the necessity for arriving at an immediate decision and united action in the matter."

The circular concludes with a request that particulars of all experiments made with continuous brakes may be sent to the Board to be laid before Parliament.

To this circular replies have been received from a few companies only; we need not reproduce them in detail. The Brecon and Merthyr Railway Company have used Fay's system for many years with excellent results. The Glasgow and South-Western Company use the Westinghouse brake on their Midland trains; and in September, 1877, they had given orders that the vacuum brake should be tried on their Greenock line. The Highland Company have been using Newall's brake since 1863, and are quite content with it. Mr. Knight, of the London and Brighton Railway, states that after making careful and exhaustive trials of the Westinghouse, Barker's, and Edwards' brakes on their line, he and Mr. Stroudley "have concluded that the Westinghouse brake is one of the most efficient, if not the most efficient, of any of the patent brakes which have yet come under our notice;" and we may add here that the directors have recently given orders for the general adoption of this brake on their lines. The Manchester, Sheffield, and Lincolnshire Company have adopted the Smith's vacuum brake, but they argue at the same time that continuous brakes are likely to become a source of danger, and in illustration of this, they call attention to an accident which occurred on the Cheshire lines system. The question raised here is important, and we shall consider the value of the argument in a moment. The North British Company have decided to adopt the Westinghouse brake, the Rhymney Company use Fay's brake; the South-Eastern Company, after taking much credit to themselves for all that they have done to promote improvements in working railways, state that they have decided to adopt the vacuum brake. To the circular and the correspondence which we have just noticed, is added an appendix containing copies of the reports of the officers of the Board of Trade on all recent accidents which might have been avoided or mitigated by the use of continuous brakes, a copy

of each report having been sent to the company concerned. There are in all ten of these reports, dealing with accidents which took place between August, 1877, and the first week in January, 1878. Of these ten accidents no fewer than six occurred on the London and North-Western Railway, by which twenty-nine persons were injured, one was killed, and much damage was done to rolling stock.

The Manchester, Sheffield, and Lincolnshire Company hold, as we have said, that continuous brakes introduce a new source of danger, and they cite, in proof of this statement, a collision which occurred on the 2d of January, at Stockport. In this case the 8.45 a.m. train from Liverpool to Hull ran into a goods van because the vacuum brake would not act, the cause of failure being that a pin came out and the steam could not be turned on to the ejector, and so no vacuum was made. We quite agree with the Manchester, Sheffield, and Lincolnshire Company, that a brake liable to such a derangement may readily become a source of peril; but nothing can be more absurd than to draw the conclusion that because one system of brake failed in this way, all systems must be treacherous. The remedy lies in using brakes which will go on and stop the train if the apparatus becomes deranged, or will otherwise show that they are out of order. The brake, in a word, should be so made that it will report its own delinquencies, and not leave them to be found out at the last moment. We have heard it argued that much inconvenience will result from the introduction of such a novel principle as this; but in point of fact, it is not new in relation to railways. On the contrary, it is followed out on almost every railway in the kingdom. When, for example, the wire for working a distance signal breaks, the arm flies to danger. The result is, that a train *may* be stopped at the wrong time. A train fitted with a continuous brake should be unable to run a mile with the brake out of order, and that this result can be secured is perfectly well known to all who are acquainted with the working of the Westinghouse automatic brake, and one or two other inventions. If the Manchester, Sheffield, and Lincolnshire directors had but used

their opportunities they could have cited instances which tend much more forcibly than the Stockport collision to prove that it is quite possible a bad brake may cause accidents. We allude to events on the London and North-Western Railway system, which tend strongly to show that the Clark and Webb brake is entirely untrustworthy. In fact, it appears to be by far the worst continuous brake ever used to any extent on a great railway.

We have already pointed out that no fewer than six accidents have recently occurred on the London and North-Western system, all which might probably have been avoided by the use of an efficient continuous brake. The first of these was a derailment which took place between Moore and Warrington on the 15th of August. In this case the train ran more than half a mile, notwithstanding every effort of the driver to stop it, because the Clark and Webb brake would not act. The second was a collision which occurred on the 3rd of October at Eccles Junction. A fast train from Liverpool to Manchester ran into an engine and van, killing the driver and doing much injury. The train was fitted with the Clark and Webb brake, which could not be applied throughout by the driver. The third accident took place on the 29th of October at Ordsal Lane. The 7 p.m. passenger train, though fitted with the Clark and Webb brake, ran into a light engine. The train was only going at twenty miles an hour, and yet it ran 200 yards in spite of every effort made to stop it. The fourth accident was a collision which took place near Willesden, between a passenger train and a goods train. It was a serious accident, eight passengers and five of the company's servants being injured. The passenger train was only moving at fifteen miles an hour, when the engine took a wrong pair of points and ran into a train standing seventy-two yards from the points in a siding. In this case it seems that the brake did not act with sufficient promptitude. Had it been really efficient the train would not have run much more than one-third of the distance. The fifth accident took place at Duston, between Northampton and Blisworth, on the 7th of November; here again a passenger train ran into a goods

train. No continuous brake was in use. A sixth accident, which occurred on the 9th of December, near Blaby, is very instructive. The engine of a mixed goods and passenger train broke away and the train followed and ran into it. In this case no accident would have occurred had the train been fitted with an automatic brake, which would have at once gone on the moment the engine broke away.

It will be seen from these examples that a so-called continuous brake may prove a source of much danger. Sensible people will say, why use such a brake?

The Board of Trade has spared no pains to induce the London and North-Western Company to abandon an arrangement which seems invariably to fail when it is most wanted. In reply to an urgent letter on the subject, dated 1st of October, the Board of Trade received

on the 19th of the same month a letter saying that "the directors were still sanguine that when all the appliances are completed as they intend them to be, the system they have adopted will comply with the required conditions." The Board of Trade, however, has told the company very plainly that it is "unable to entertain much hope that the expectations of the directors will be realized," and it has since specially called the attention of the company to every accident bearing on the value of the Clark & Webb brake; but so far as the parliamentary paper before us goes, it seems that the company have taken no notice of these communications. Yet it may be taken for granted, we think, that a system which cannot be made to work by so competent an engineer as Mr. Webb, with all the resources of Crewe to aid him, can hardly be made to work at all, and should be abandoned forthwith.

## ON THE CHEMISTRY OF STEEL.

By WILLIAM BAKER, A. R. S. M., F. C. S., F. Inst. Chem.

From "Iron."

THE facts which are known about steel have hitherto been distributed on the one hand amongst manufacturers, practical steel melters, and other workmen. But the facts have been of a certain kind for each of these observers, and comparatively few persons have had the opportunity or the inclination to grasp them all, and correlate them for future guidance, even for practical purposes. On the other hand, a different class of facts have been known by chemists, such as relate to the general properties of matter and the special properties of iron and its compound, as far as they can be studied in the laboratory, or by the occasional sight of some of the large metallurgical operations of the factories.

The time, I hope, is passed when these observers of different classes of facts were supposed to stand in some sort of opposition as men of theory and of practice; but my observations of the numerous unexplained difficulties occasionally occurring in the best conducted manu-

factories, convince me that a much greater certainty in results would have been attained if these scattered observations had been tested by comparison, and reviewed in a comprehensive manner by a trained scientific mind.

It is not for me to say how far one is justified in asking manufacturers to reveal the secrets which they suppose have led them to success; and I imagine, if any of you can buy a common iron, and make as good steel as your neighbor, who buys a higher-priced article, you would prefer to keep the knowledge to yourselves. The economy of material and of money which would result from the better knowledge obtained by an opposite policy, would, however, bring about the greatest benefit to the greatest number, and leave plenty of scope for fair rivalry in commerce.

I must premise that I am not acquainted with all the curious observations which may have been made in a steel factory, and with which many of

you are quite familiar; but my intention is to exhibit to you a chemist's view of the nature of steel, and to point out the path for experiment and the probable extent of its track.

*Characters of Pure Iron.*—In order to understand steel, we must begin by an examination of the properties of pure iron, or at least of iron in the purest form attainable.

The method originally recommended by Berzelius to obtain pure iron from the wrought iron of commerce was to fuse the filings with one-fifth of their weight of pure peroxide of iron under a flux of glass free from metallic impurities. Percy did not find the product thus obtained free from carbon. The specific gravity was 7.87 after hammering. The fracture was largely crystalline, greyish-white, and the metal was soft and malleable. Electro-deposited iron has been produced which did not harden when plunged red-hot into mercury, and which dissolved in dilute acid without the peculiar odor given off by every kind of commercial iron. These results prove the absence of carbon, but do not exclude the presence of nitrogen, which I am disposed to think, from the physical characters of the metal, may have been combined with the iron. The specific gravity was 8.1393, and the metal was susceptible of a high polish.

The investigation of the production of pure iron, and an examination of its properties, are well worthy the attention of chemists who have sufficient leisure; and I hope, if the British Association meet in Sheffield, the members may be inclined to take up again the question, which has somehow dropped out of the proceedings after it had been entrusted to a committee for report.

Two observers, Meidinger and Kramer, agree in stating that about 1.5 per cent. of nitrogen was found in precipitated iron.

I possess some iron containing nitrogen, which I obtained by passing dry ammonia over it at a red heat. It is a brittle steel-grey alloy, and contains 5.76 per cent. of nitrogen, represented nearly by the formula,  $\text{Fe}_8\text{N}$ .

Iron crystallizes in the cubical system. Its structure may be studied in masses which have been submitted for a long time to a heat short of fusion. The

fracture is largely granular, and possesses a brilliant metallic luster. A section of such iron, when highly polished and etched for a microscopic object, is very characteristic. It exhibits a network of irregular hexagonal forms, which may be at once recognized in all samples of wrought iron, whatever their source. The Bessemer iron, before the addition of spiegeleisen, exhibits the same pattern as a bar of wrought iron or a wrought iron axle, the only difference in the various samples being in the size of the crystals. A slice from a Bessemer ingot still exhibits the same network of hexagonal-shaped crystals, but possesses, besides, some harder portions, due to the spiegeleisen, which strike across the spaces like bright silver threads, and the crystals themselves, seen by the light of a parabolic reflector, have more distinct prismatic colors.

It is easy to understand how a mass of iron deprived of carbon, and having these large crystals developed, is deficient in tenacity. The Bessemer ingot, however, when hammered and rolled, has a very different appearance, and cannot be distinguished from ordinary crucible steel. The nearest approach to pure iron we have on the large scale will be found in the softest bar iron of commerce, and I will examine how this stage of manufacture is reached, and what elements may be expected to be contained as impurities.

*Production of Steel from Cast Iron.*—Originally steel was produced, as it is to this day in India and less civilized countries, by working the bloom or mass of iron reduced from rich ores in a charcoal-furnace under the blast. Afterwards cast iron was first made, and although Siemens has again introduced a direct process of reduction from the ore, we may consider that, practically, to make steel, we must start with cast iron.

Cast iron presents us with a metal containing carbon as an essential constituent, and the following elements besides as impurities:—Silicon, sulphur, phosphorus and manganese. It may also contain copper and traces of cobalt, nickel and titanium.

The art of the smelter consists in adjusting the charge of the furnace in such a manner that when the iron is reduced it may have time during its descent in

the blast-furnace to absorb the desired quantity of carbon, whilst the other elements, or at least the hurtful elements, such as sulphur and phosphorus, should be taken up by the slag or cinder.

Iron absorbs carbon when heated in contact with it at a bright red heat. It will also take up carbon from pure carbonic-oxide gas, and this, it must be remembered, is the chief gas present in the furnace. Accurate experiments are wanting as to the rate of absorption for varying temperature and pressure; but I have found that whereas at a moderate red heat carbonic oxide is decomposed if passed in excess over red-hot iron, when it is passed through the melted metal containing already about 1 per cent., no increase was observed at this far higher temperature. At the high temperature of the blast-furnace, silicon is also reduced, and absorbed by the iron. A siliconized pig-iron is now a variety which is of great service in the Bessemer works for producing a "hot-blow;" and I have analyzed some grey pig-iron containing as much as six and seven per cent. Sulphur is an impurity which is not so much dreaded as formerly; as it is easy, by a proper addition of lime and by management of the furnace, to prevent more than a trace appearing in the pig-metal.

This cannot be said of phosphorus, which is present in iron ores as phosphoric acid. The process of smelting, as carried on in the blast-furnace, unfortunately effects the reduction of the acid, and practically the whole of this element is found in the iron produced. Manganese appears more or less in pig-iron, according to the amount of its oxide in the ore employed. When a notable quantity is required in cast iron, as for spiegeleisen, the charge must be adjusted so as to allow for some of it being also found in the slag. As a rule, when iron and manganese oxides are together, the whole of the iron oxide is reduced before the manganese; so that when a good fusible cinder is produced of the usual composition—silicate of lime and allumina—it is common to find a proportion of manganese oxide replacing the lime.

The traces of other metals occurring in cast iron rarely affects steel, as they disappear in the processes of manufacture.

#### *Combination of Carbon and Iron.*—

The combination of carbon with iron is so extraordinary, and presents such unexplained facts, that I must dwell for a short time on this part of my subject. Starting with pure iron, it is found that the addition of a very small proportion, say 0.2 per cent., imparts the property of hardening slightly when heated and suddenly cooled. With increasing quantities of carbon this phenomenon becomes more striking. With about 1.5 per cent., steel, after hardening, acquires its maximum hardness with maximum tenacity. Beyond this quantity greater hardness is obtained, but there is a loss of tenacity and property of being welded. The maximum amount of carbon which will combine with iron alone, has not been yet ascertained. When manganese is present, as in spiegeleisen, it may rise to a little above 5 per cent., but more frequently is slightly below this figure.

We have, however, this remarkable fact to account for. Carbon exists combined chemically, and also in a free state, as in the form of graphite, and this distinguishes white from grey iron. Chemical analysis affords proof of this fact, and solution of the iron in acid actually discloses scales of graphitoid carbon.

White iron, on the contrary, dissolves with scarcely a trace of carbon being left behind. "Gray iron has a higher melting point than white iron, and on fusing passes almost instantly from the solid to the liquid state when it is very fluid; whereas, white iron at lower temperatures becomes first soft and then pasty before melting" (Percy).

These facts, to my mind, point to the presence of a definite carbide in white iron, which may be considered in solution with the iron, and the pasty condition is due to the fact that the iron solidifies before the carbide. The crystallization of white iron is quite distinct from iron alone. We have, then, to account for the higher melting point and quick solidification of grey pig iron, and I think, if we consider the fact of the specific heat of carbon being double that of iron, we have a key to the explanation. The melting point of iron *per se* is known to be very much higher than iron containing carbon in combination, but when free carbon is dissolved

in the iron, the heat retained by it, by reason of its specific heat, may favor the fusion. What conditions determine the form in which carbon is found in iron, have not been altogether satisfactorily made out. We know that when bar iron is heated in contact with charcoal, as in the steel-converting furnaces, the carbon enters, and is found in the combined state. I examined some bars once which had run from overheating in one of these furnaces, and wherever fusion had taken place the bar was no longer blister steel, but grey iron. The percentage of carbon was only a trifle higher in the grey portion.

In some experiments I lately made, I passed chlorine, carbonic acid, and carbonic oxide frequently through molten iron of the quality No. 3 Middlesborough pig-iron. I found it very difficult to obtain the ingot in the form of grey iron by the artifice of very slow cooling. It is probable the presence of phosphorus to the extent of one-half per cent. had considerable influence in keeping the carbon chemically combined.

Silicon is also supposed to occur in the graphitoidal state in such varieties of iron as No. 1 Bessemer pig, but in steel it is, without doubt, in chemical combination entirely. Sulphur and phosphorus both render iron harder and more fusible.

#### *Conversion of Cast Iron into Steel.*

Having reviewed thus shortly the most important facts connected with the presence of these substances in cast iron, let us examine how far the processes of conversion of pig-iron into steel effects their elimination.

The pig-iron is puddled to make bar iron. This process is essentially an oxidizing one. Silicon oxidizes first, then, as the carbon is removed, sulphur and phosphorus are also oxidized and pass into the slag. Only towards the end of the process, when the heat is much increased, the phosphorus is retained by the powerful affinity iron has for this element at high temperatures.

Mr. Lowthian Bell has lately brought out this fact very prominently by a series of carefully executed experiments, together with analyses, although it cannot be said that the behavior of phosphorus under the conditions were unknown. I mean, it was known that with an oxidizing cinder, phosphorus could be removed,

and that at the end of the process, if the slag were still in contact, this element would again return to the iron. However, Mr. Bell has more accurately defined the conditions of its elimination in his paper read at the last meeting of the Iron and Steel Institute.

If we turn to the Bessemer process, we find that, with somewhat different conditions, we have also to deal with an essentially oxidizing reaction. The slag, however, which is formed is not basic; the oxidation is direct by means of the oxygen of the air, and no phosphorus is eliminated. All the other substances may be removed most completely, silicon first, carbon and manganese afterwards. We approach the production of fused wrought iron, and one reason we are not able to succeed in getting the metal into the ingot moulds appears to be the enormous volume of carbonic-oxide gas which it has absorbed. Another is the sudden oxidation of the iron itself, which, following the order of affinities for oxygen at this high temperature, begins to burn when the last portions of carbon are removed.

The addition of metallic manganese has a wonderful effect in reducing the oxide and liberating the occluded gas, so that, without going to the extent of oxidation which I have indicated, spiegeleisen, or ferro-manganese, enables us to obtain an ingot which may contain only 0.25 per cent. of carbon; silicon, perhaps, to the amount of 0.1 per cent., sulphur in traces, and, lastly, according to the quality of the original pig-iron, phosphorus from 0.01 to 0.05 per cent.

Going back, however, to the puddled bar iron, which has been washed in a bath of slag, balled up and hammered into bar, we have a tough metal, which is, however, not homogeneous, because it has not been fluid during the last stages of the operation. It contains portions of slag and oxide of iron besides the impurities in combination. It is true the latter may be in very insignificant quantities. Silicon is often recorded to the amount of 0.3 per cent.; but, in many cases, this includes the silica due to intermixed slag.

It is the oxide of carbon mechanically enclosed in the bar which produces the blisters on the converted bar. The regularity of the blisters show the work

which has been put upon the metal in balling up and treatment under the hammer.

I will now follow the bar to the converting furnace, where it is heated with charcoal at a full red heat. The atmosphere of the cementing pot is undoubtedly chiefly carbonic oxide. Hydro-carbons retained in the charcoal, and possibly cyanogen, with atmospheric nitrogen, may also be present. Whatever may be the value of the last-named gas for conversion of iron into steel, I can affirm confidently that pure carbonic-oxide gas alone, without actual contact with charcoal, is all-sufficient for the purpose.

Of the impurities, silicon, manganese and phosphorus remain, whilst sulphur is slightly diminished in its proportion. The charge itself, gaining in weight by the operation, will of course exhibit a slight diminution in percentage composition of silicon, phosphorus and manganese.

The iron has now acquired the desired proportion of carbon; let us examine what changes can take place in melting the same. Silicon may be slightly diminished by oxidation. Sulphur, if existing in any appreciable proportion, is also diminished if manganese be added, as is usually the case. Phosphorus remains untouched. Silicon may sometimes be increased in mild steel, which requires a high temperature for fusion in consequence of the reducing action of carbon in the pot upon the silica in the clay.

But bar iron may be melted with charcoal direct, or with spiegeleisen, in order to produce cast steel, and certain differences of character are alleged to be discovered in the products of these three operations when the same bar iron has been employed.

Now, with all respect to the observers, who, I am sure, have founded their opinions upon practical results, I venture to suggest that the observations and experiments to determine these differences have not been put into the scientific form which will alone educe the truth. A scientific method would first establish identity of chemical constitution, and next, the mechanical tests should be rigidly the same, and of such a character as to be independent of opinion and capable of being recorded in figures.

When charcoal is used, I cannot see, as a chemist, that any appreciable amount of foreign matter, except the carbon, is in contact with the iron, and precisely the same quantity of steel ought to be produced as when blister steel is melted.

Spiegeleisen does, however, introduce manganese, traces of sulphur and phosphorus, and not unfrequently copper, which may all alter the constitution of the steel.

Again, the comparisons should be made with the same temper, and the ingots tested by a machine using exactly similar dimensions of each kind of steel, as in the well-known experiments of Kirkaldy. There is an excellent report on the mechanical properties of steel in the British Association Report of 1867, by Fairbairn, which would be doubled in value if a chemical analysis of each specimen had been recorded. Even now it is quite possible that some typical samples might be recovered for this purpose.

*Steel Melting.*—Any one who has cast leaden bullets knows that when the lead is hot and the mould has got hot too, the bullet is piped. It is so with steel. Well-melted steel pipes, and any substance which confers fusibility to steel, like ferromanganese, tends to make it pipe.

The carbonic oxide which is absorbed by melted steel produces an opposite effect; the steel rises in the mould, and is full of "honeycombs" or gas bubbles. The proportion of this occluded gas and its relation to different qualities of steel, or different behavior in "teeming," have not yet been properly worked at, and in my opinion are well worthy of investigation.

In what manner the physical characters of steel are influenced by the time and the temperature of melting, and by the interval between the pulling out and the teeming into the moulds, are subjects which require definition and some accurate measurement before we can reconcile some of the statements made by men of undoubted experience.

Perhaps the instrument of research which is most needed is a good pyrometer, and I think it is not improbable that some spectrum observations may lead to the discovery of a useful guide to

the measurement of high temperatures. The compression of steel whilst in the pasty state before complete solidification has, in Sir Joseph Whitworth's hands, produced ingots remarkably free from the honeycombed structure caused by bubbles of gas. The difficulties in practice seem to me to be in dead-melting the steel in the first place, and then, after removal from the furnace, choosing the period when it will pour without piping.

The grand point aimed at by all steel melters is to obtain tough steel, and they mean by this, I presume, a steel hard enough for the purpose required, with a maximum tenacity. At least, more than that is not possible; for toughness and hardness are really opposite qualities, and the utmost that can be attained is a suitable relation between these properties for a given purpose.

It is certain that the purest steel is the toughest. Absence of silicon, sulphur and phosphorus are, at all events, essential for the best results. It is yet to be proved whether a small proportion of metallic manganese imparts more tenacity to steel; but there is some ground to believe that it does. I think I am right in stating that it confers the property of standing repeated heating, which is known as "body" in steel.

Besides carbon, we know that the three elements, silicon, sulphur and phosphorus, singly or all together, will harden steel. The experiments made by the Terre Noire Company show that when the carbon is replaced by phosphorus, and the former is not more than 0.2 per cent., a serviceable rail can be made,

containing as much as 0.3 per cent. of phosphorus.

It is also established that a good wrought iron may contain as much as 0.2 per cent. of phosphorus, whereas the attempts to make tool steel of such a material would be a failure. In fact, phosphorus cannot be admitted when carbon is present in the proportion which confers the properties of hardening and tempering.

Time will not permit me to enter fully into the effects of other materials which are likely to be used methodically in the production of certain kinds of cast steel, such as wolfram or tungsten, chromium and titanium. Generally it may be said that they produce greater hardness and closeness of grain, but none appears to play the part of carbon in conferring the property of hardening and tempering.

This interesting phenomenon belonging to ordinary steel has not been thoroughly investigated, and the influence of the occluded gases I think may furnish a new field of observation.

I have thus reviewed the present state of our knowledge of the chemistry of steel without quoting authorities whose opinions I have myself carefully studied and compared with my own observations. The subject demands a leisure which I have long looked for in vain, whilst engaged in the daily work of my laboratory. What I have done in practical experiments convinces me that a much greater certainty would accompany the operation of making steel if some of the questions I have indicated were decided by a well-conducted and scientific research.

## STEEL MARINE BOILERS.

From "The Engineer."

It will be seen from a report which we publish on another page, that Mr. W. Parker, chief engineer surveyor, and Mr. James Milton, engineer surveyor, to Lloyd's, advise that society to permit in future the use of steel boilers, the shells and stays of which may be made 25 per cent., and the flat plates 12 per cent.,

smaller in scantling than would be admissible if similar boilers were made of iron. Lloyd's have already sanctioned the use of steel in shipbuilding, and the adoption of the report of Messrs. Parker and Milton will constitute another step in advance. It will be seen, however, that steel is only to be used under cer-

tain stringent regulations as regards the tests to which the plates are to be subjected; and it is not too much to say that it is only within a very recent period that it became possible to obtain steel with anything like certainty, and at a reasonable price, which would meet the demands thus made on it. A very elaborate inquiry has been conducted by Mr. Parker, and the result is that steel capable of standing a tensile strain of 28 tons to the inch, and elongating 20 per cent. before fracture, can now be obtained; and it is this really wonderful metal that steel boilers are to be made of. It is evident that nothing would have been gained by sanctioning the use of steel of a quality which could not be had; and we feel certain that gentlemen so careful and competent as Mr. Parker and Mr. Milton would not have introduced the stipulations laid down in their report had they not been convinced by practical experience that a metal existed which would comply with them. This metal is now made by at least three great firms, and it is worth notice that it can be obtained at a reasonable price—the quotations for boiler plates 1 in. thick ranging from £15 to £21 per ton, with different makers. But even this excellent metal requires very careful handling, and on this point a few words may not be out of place here. Those who attempt to make a steel boiler as they have made iron boilers, will soon find out to their cost that steel is a very different metal indeed from iron.

In the first place, holes in steel boiler seams should always be drilled. When steel plates are punched they lose from 26 to 33 per cent. of their strength. A paper was read by Mr. Sharp before the Institution of Naval Architects in 1868, in which the author gave as the result of his experience a loss of 33 per cent. Mr. Kirk, in a paper read before the same body in 1877, gave similar figures; so that it will be seen that the improvements effected in the mode of manufacturing steel during nine years have left this point quite untouched. Mr. Webb, of Crewe, states that the loss of strength is but 26 per cent.; but Mr. Webb in punching steel uses a die-block with a hole much larger than the punch, and the holes produced are conical with the large side down. The investigations of Mr.

Parker fully confirm the teachings of past experience, and a material which is apparently almost as ductile and “kind” as lead, no doubt loses about one-third of its strength when punched. This is a curious fact well worth proper investigation. All sorts of other defects in steel appear to be curable, but this has hitherto remained unaffected by any change in the process of manufacture. It has been shown, however, that the plate may be restored after punching to nearly if not quite its full strength by annealing. The word is not happily used in this case, the plates not being annealed at all in the true sense of the term, but simply reheated. It is a mistake to assume that if they are not cooled down slowly after heating they must become brittle. The plate might be thrown into cold water when red-hot without injury, provided it could all be cooled down at once. A prolonged process of cooling is required only because if the work is hastened some portions of the plate may be cooled more quickly than others, and the value of the so-called annealing process will be lost. It was hardly known until now that steel plates suffer most as much from shearing as from punching, and that similar precautions must be taken to restore the strength of the material. It appears, however, that notwithstanding these drawbacks, if the advice given in the report be followed, especially as regards flanging plates, steel may be worked into boilers with the certainty that a good result will be obtained.

As regards the proportions to be given to the riveted joints of steel boilers, Messrs. Parker and Milton do not speak positively. We may say that experiments are still in progress to decide this point, and that for the present it is considered best that for each boiler to be constructed a direct experiment shall be carried out to ascertain the proper proportions. Enough is known, however, to show that the proportions used with iron will not do with steel. The metal is so soft that it cripples or puckers up behind the rivets, which can't in the plates. The holes become oval and the seams leak long before anything nearly approaching the bursting pressure is obtained. Excellent results have been got with a double chain riveted joint, the plates being  $1\frac{1}{8}$  in. thick, and the rivets  $1\frac{1}{8}$  in. thick, pitched

4 in. apart. This joint had a strength of 74 per cent. that of the plate. But we do not put these forward as the proportions which ought to be always adopted. No trials have been made, we believe, with oval rivets, the value of which might be worth testing.

No doubt many of our readers will ask what can be gained by substituting a material so peculiar, and requiring such careful manipulation, for iron. The reply is, that on the whole a steel boiler will cost less money than an iron boiler of the same power. It is very rarely that anything better than B B iron is used for the shells of marine boilers. This is good for from 18 to 21 tons per square inch, 19 tons may be taken as almost the average. If we substitute for it a metal which will bear 26 tons, a corresponding reduction can be made in weight, or an increase can be made in pressure. It must not be forgotten that the consideration with which steel must be treated when being worked into a boiler is, after all, not costly. The reheating plant is very simple; and the operation of flanging can be readily effected *en masse*, instead of a few inches at a time, if proper cast iron blocks are provided. The marine boiler makers of Great Britain might learn something concerning the flanging of steel from Messrs. Garrett, of Leiston, who have long used Piedbœuf's machinery for this purpose, with great success. Once a steel boiler is made, the risk of injury to the plates appears to be over, and, so far as can be learned, something is obtained, which is stronger, lighter, and more durable than any iron boiler. The only thing to be feared is pitting and corrosion, and on this point it is impossible to say much with certainty, as the number of steel boilers which have been at work for any time at sea is extremely limited. We have reason to believe that the moment Lloyd's sanction the use of steel boilers, a considerable number will be made. Many shipowners want to carry pressures of 120 lbs. in boilers 12 feet and 13 feet in diameter, and it is found that iron plates  $1\frac{1}{4}$  inch thick cannot be made tight, or kept tight at the joints; that they are very expensive to work up, and that the quality of such plates is by no means all that could be desired. As pressures as great as 90 lbs. are already

carried at sea, if steel be substituted for iron, instead of reducing the scantlings 25 per cent., the pressure may be increased 33 per cent., and 90 lbs. steam might thus become 120 lbs., or even a little more; for it is by no means impossible that the factor of safety in the steel boiler may yet be reduced below the six to one limit now insisted upon by Lloyd's rules.

## REPORTS OF ENGINEERING SOCIETIES.

**ENGINEERS' CLUB OF PHILADELPHIA.**—At a meeting of the Club, held February 16th, twenty members were present, and ten new members were elected. Mr. Chas. A. Ashburnet read a paper entitled "Where is Petroleum found?" After noticing some of the many points of interest concerning our petroleum industry, which have been brought before the public during the recent "pipe line" discussions, the author gave a general sketch of the various "Oil bearing sands," giving the geological position and character, and the quantity and quality of petroleum which they at present produce. The oil regions of Pennsylvania were divided into three districts, viz.: the Southwestern, South of the Ohio River and West of the Monongahela River; the Western, along the Allegheny River and tributaries between Pittsburgh on the South, and P. & E. R. R. on the North; and the Northern District, North of the P. & E. R. R. extending into New York State.

In Pennsylvania, three thousand feet of the rocks of the Carboniferous and Devonian ages have been found to contain mineral oil. The highest producing sand occurs in Washington Co., 165 feet below the Pittsburgh coal seam, the lowest in McKean Co., 3,200 feet below the geological position of the same coal bed. The Bradford oil, in McKean Co., comes from a horizon 400 feet above the lowest.

On a basis of a daily production of 40,000 barrels, each of the nine different sands in which oil is found was given its respective production.

In speaking of the percentage of risk which the producer experiences in obtaining dry holes, the South-Western district was stated to be the most treacherous, and the Northern the safest, for in the latter the proportion of dry holes is only three wells in every hundred.

Specimens of the "sands" and crude oils were exhibited and formed an interesting feature of the paper.

Mr. Geo. H. Christian, Jr., followed with a paper on the "Lowe Gas Process," which was illustrated by a large sectional drawing, and a view of the new gas works at Lancaster, Pa. Mr. Christian gave a full and interesting description of the plant in one of the works of the American Water Gas Co.

The various chemical changes which take place in the course of manufacture were noted and the cost of manufacture, wear and tear of plant, &c., were given. The advantages possessed by gas made under this process were

clearly shown, and the reasons why this superior and economical gas has not been introduced into our city were stated to be entirely of a political nature.

At a meeting of the Club, held March 2d, twenty two members were present. Mr. Rudolph Hering read an interesting paper on "The Sewerage of Philadelphia." This is a subject which is all important to the welfare and health of the city, and one which has received close and careful study from the author. An abstract of this paper will be given in our next issue.

A paper on the "South Street Bridge," by Prof. L. M. Haupt was read. Estimates of the pressure on the piles, forming the foundations for the piers in the Western approach, had been calculated from data obtained from drawings in the office of the City Engineer. Prof. Haupt thought that as the piles were driven through or into soft mud, which is inundated at every tide, the pressure placed upon them was in excess of their bearing power in such soil, and the cause of the fall of the structure.

This paper brought out very general discussion.

Mr. Geo. Burnham, Jr. gave a general description of the masonry work of the bridge and presented a plan which might have been used to save part of the structure. At the second pier east of the Pennsylvania R. R. the piles were driven through 15 feet of mud to a bed of gravel. Only the north end of this pier sank, the south end remaining firm. Mr. Stauffer stated that at the railroad abutment the gravel bed was within a foot of the surface; it seemed to have a regularly sloping surface toward the river, where the piles were driven through 45 feet of mud before reaching it. Piles were all driven with a 2,000 lb. hammer, and received, as a final test, four blows from the hammer with 36 feet fall, when one inch downward motion was the maximum allowable for each blow.

The cause of the failing of the pier is not known and cannot be definitely stated until the rough examinations have been made. The fact that within twenty-four hours of the final crash there was not a vertical crack in the masonry, though the pier was sinking to the north, proves that the grillage must have been perfect.

The estimated load on the piles under the pier was 2,000 tons, amounting to 23 tons on each pile. According to Rankine, the piles were good for 8 tons frictional value, leaving 15 tons on the toe of the pile. The tremor produced in the piles by travel on the bridge would loosen them sufficiently to allow the percolation of water down their sides and finally throw the whole weight on the toes of the piles. If the bed of gravel was merely a thin bed or pocket the water probably softened it allowing a bunch of piles at the north end of the pier to drop through to the mud.

Mr. Hering did not think the removal of the roadway above the sinking pier was a disadvantage; Mr. Stauffer held that every block of coping, paving, etc., which was jammed in the invert arch in the roadway caused by the sinking of the pier, helped to convey weight to the

sound piers on either side, and that their removal threw the additional weight on the failing pier. An expenditure of \$500 in placing the rods across the arches through the skew backs would have saved seven out of the nine arches. If time had allowed to put in centres, as was proposed, they would not have been of much value without these tie rods.

The discussion of the South Street Bridge was made the special order for the next meeting.

**CIVIL AND MECHANICAL ENGINEERS' SOCIETY.**  
—At a late meeting of the society a paper "On Chimney Shafts" was read by Mr. R. M. Bancroft, past president of the society. After drawing attention to the wide difference of opinion between various authorities who have written on the subject, especially with regard to parallel and taper flues, and whether chimneys should have a regular batter or outline similar to the theoretical diminution of columns, which it is said should have a slight swell in the center of its length, the author proceeded to describe upwards of forty chimneys of which the different owners and designers had supplied him with particulars. These he had tabulated, to show, at a glance, height, thickness of wall, proportions of diameter to height, weight, cost, time of building, &c.; and drew attention to the designs of caps, and in one case noted where a cap had cost £700 in repairs and removal after the stack had been completed. Mr. Bancroft then drew attention to the difficulties in straightening chimneys when out of the perpendicular, and mentioned several successful cases where this had been done.

**A**T a late meeting of the Edinburgh and Leith Engineers' Society, a paper was read by Mr. Alexander Leslie, Member Inst. C.E., on "The Liability of Reservoir Embankments to Failure." After stating that great care should be taken to have the base of the embankment on perfectly solid ground, the writer went on to describe the construction of the puddle wall and trench, pointing out the sources of failure which are apt to occur, and giving examples from his own observations of a very great number of embankments. He mentioned that no wood used in the construction of the puddle trench must be left in, as the water is sure to creep along the smooth surface between it and the puddle, and so, in time, cause serious injury. He also stated that the practice of using wagons and rails for tipping the materials of the embankment cannot be too strongly condemned, as loose stones are sure to find their way to the bottom, and make there a more or less porous layer. After describing the method of pitching the surface, and also of constructing the waste weir and channel, Mr. Leslie gave instances of very destructive failures, such as the Dale Dyke and Holm Firth reservoirs, and discussed the causes of them. On speaking of the drawing-off pipes, it was stated that every caution should be taken to prevent any water from creeping along the surface of the pipe, as, sooner or later, serious leakage would result.

**LIVERPOOL ENGINEERING SOCIETY.**—At the meeting of this society, held on Wednesday evening, January 30, Mr. Arthur J. Maginnis read an instructive and interesting paper on "Atlantic Lines and Steamships." The author, in the early part of the paper, gave a short review of all the important companies and vessels which have been engaged in the Atlantic trade since 1840, in which year the first Cunard steamship sailed. After detailing the various schemes, more or less successful, which have from time to time been tried for reducing the passage between Europe and America, Mr. Maginnis drew attention to some of the more important improvements, considered from an engineering point of view, introduced in the vessels of the White Star and other lines. Among these may be mentioned direct acting compound engines; and in the hull of the vessel itself, the proportions of length and breadth are increased, and the bulkheads carried up 16 feet above the load line. The advantage of these improvements may be estimated from the fact that while the speed of Atlantic steamers has increased from 8.3 knots to 15.6 knots, the consumption of coal, per indicated horse power, has decreased from 4.7 cwt, and the consumption of coal per ton of cargo delivered has decreased from 48.35 cwt. to 44.5 cwt. The paper included some instructive tables carefully compiled from official sources.

### IRON AND STEEL NOTES.

**STRENGTH OF IRON AT DIFFERENT TEMPERATURES.**—G. Pisati and G. Saporito-Ricca find that the strength of iron at different temperatures shows peculiar irregularities. The strength in a wire which is exposed to a dull-red heat diminishes, with increase of temperature, from 14° to 50°, then increases to 90°, diminishes rapidly to 120°, remains constant to 200°, sinks slowly to 235°, then comes a sudden increase, which is followed by a gradual diminution. The strength is greater at 300° than at 140°.—*Dingler's Journal*.

**STEEL BOILERS.**—The report of Mr. William Parker and Mr. James Milton, Chief-Engineer-Surveyor, and Engineer of Lloyd's, on Steel Boilers, is an important and carefully-prepared document. After careful enumeration of the experiments made, and the evidence collected, the conclusion is arrived at that, "in the construction of steel boilers, greater care and attention must be exercised with the workmanship than is required in the case of iron boilers;" that, although the corrosion of the steel boilers examined is excessive, they may, "if made with the care that this material requires," eventually prove as durable as iron boilers, and, that it will be a question whether a considerable reduction in the factor of safety may not be found compatible with perfect safety and efficiency. It is therefore recommended that a reduction from the scantlings prescribed by the rules for iron boilers be made in the shell plates and stays to the extent of 25 per cent.; and in the flat plates not subject to the action of heat, to the extent of 12 per cent., on

condition that the material have an ultimate tensile strength of not less than 26, and not more than 30 tons per square inch of section; that a strip cut from every plate be tested; that the holes be drilled, or if punched, the plates be afterward annealed; that all plates, except those in compression, that are dished or flanged, be afterwards annealed; and that the boilers be tested to not less than twice their working pressure.

**RESISTANCE OF STEEL AND COMPOSITE PLATES.**—In continuation of the experiments which took place at Portsmouth shortly before Christmas, with the view of ascertaining the power of resistance of steel and composite (steel and iron) plates, two plates, manufactured by Messrs. John Brown & Co., the Atlas Works, Sheffield (Ellis's patent), were on Wednesday subjected to the same test on board the *Nettle*, target ship of Her Majesty's ship *Excellent*, in Porchester Creek, at the upper part of Portsmouth Harbor. On the former occasion the experiments were made with four plates, three supplied by Messrs. Cammell & Co, and the other by Sir Joseph Whitworth. The plates operated upon on Wednesday were respectively 7 feet 9 inches by 6 feet 8 inches, and 7 feet 6 inches by 6 feet 6 inches, and 9 inches in thickness. Three shots were fired at each plate from a 12-ton 9-inch muzzle-loading rifle gun, at a distance of 30 feet, the charges being 50 pounds of battering pebble powder, and the projectile called chilled Palliser shots 250 pounds in weight. The three shots fired at the first plate each penetrated about 10 inches, and created more than a dozen deep fissures, some penetrating through the plate, besides superficial cracks. On the second plate being fired at, the penetration of the first and second shots was about 9 inches; the third shot proved most damaging, the left section of the plate being carried away, and falling with a crash on the floor of the floor of the battery.

**FINE STEEL CASTINGS.**—A patent has been recently taken out by Mr. A. J. Nellis, of the Pittsburgh Agricultural Works, in favour of a process for making irregular-shaped castings, such as plough-shares, out of fine tool steel, of any desired percentage of carbon, without annealing, as in the ordinary "steel casting" processes. In the ordinary method of making steel castings, it is necessary for the steel to be very high in carbon, in order to be fluid enough when melted to run into a fine casting, and the excess of carbon is removed after the casting is made by a process of annealing which requires from ten to twenty days. By Mr. Nellis's method of making castings, low carbon steel, or ordinary tool steel, may be employed if desired. The mould in which the casting is formed is impregnated with combustible materials, which takes fire the instant that the melted steel comes in contact with the mould. An intense heat appears to be generated, which retains the steel in a perfectly fluid condition till it reaches the smallest corners of the mould, and an agitation is caused by which all air and confined gases are allowed to escape from the metal, thereby making the casting free from blowholes. One theory of the action of this

process is that the combustion of the materials with which the sand is impregnated consumes all the oxygen of the air within the mould, and that the remaining gases have no "affinity" for the steel. The plough-shares made by this process can be forged into any shape required by an ordinary blacksmith, or after it is entirely worn out he may draw it down into tools and cutlery. If the new process succeeds as well as it promises to do, we may soon see steel castings largely used instead of wrought iron or steel forgings for all difficult shapes. Mr. Nellis also has a patent on the mould used for his steel castings, which obviates the trouble experienced with iron moulds, of the melted steel adhering to them on all sides, and causing shrinkage cracks, and has all the advantage which iron moulds possess of durability and permanence of form. The moulds are made chiefly of iron, but with inserted sections of sand. These sections do not adhere to the casting, and shrinkage can take place without hindrance, avoiding cracks or internal strains.—*American Manufacturer.*

### RAILWAY NOTES.

THE directors of the London, Brighton, and South Coast Railway Company have for some time past had under consideration the question of break power for their trains. Several kinds of patent breaks have been experimentally tried on the Brighton Railway, and particulars have also been obtained by the general manager and locomotive superintendent of that line of the various patent brakes at work both in this country and abroad, and, guided by general information and practical results of this kind, the directors have decided upon adopting the Westinghouse automatic brake for the passenger trains upon the Brighton system. Accordingly, an initiative order has been given by the Brighton Company for the fitting up of fifty engines and 500 carriages with the Westinghouse brake apparatus. In the course of a few weeks, therefore several of the London and Brighton express trains will be equipped with this efficient continuous break. In selecting the Westinghouse break the Brighton directors are of opinion that they will obtain for their passenger trains a continuous brake which will comply in all respects with the conditions laid down by the Board of Trade authorities. It should be mentioned also that the Brighton Company have for some time past had a large number of their engines fitted up with an efficient steam break designed by their locomotive superintendent, Mr. Stroudly. The Western Railway of France Company, with whom the Brighton Company have working arrangements for the through traffic between London and Paris by the Dieppe route, have likewise decided upon introducing the Westinghouse automatic brake in their trains between Dieppe and Paris, and other parts of their line.

IT was stated in the course of a recent debate in the Prussian Lower House that at the present time nearly half the railways in the kingdom are the property of the State, or

under Government management. There are 10,625 miles of railway in Prussia, of which 5500 miles belong to private companies, while 2937 miles belong to the State, and 2188 are worked by Government. Three years ago the respective proportions were 4509 miles belonging to private companies, 2522 miles belonging to the State, and 1542 worked by it. Thus there is an increasing tendency upon the part of the State to acquire the private lines, and the reform of the traffic which the Government has decided upon with regard to its own lines, but which the private companies are unwilling to accept, is expected to lead to a struggle which will probably end to the disadvantage of the latter. The struggle is not confined within the frontiers of Prussia, for its policy with regard to the railways concerns the whole German system, as there is a great competition between the Prussian main lines worked by the State and the parallel lines in other parts of the empire. During the same debate the Minister of Commerce, questioned as to the policy of his Government, said that he was not in favor of the absolute system of State railways: "The Government merely wishes to acquire, by possession of some lines of its own, the power of exercising a regulating influence over the whole railway system. This is why we have sought to gain possession of the lines which had almost a monopoly of traffic, and we cannot see how such a step can have created any alarm among railway shareholders at large."

THE report of the Ministerial Department of Crown Lands and Public Works at the Cape has recently been published, showing, among other information, the progress made in railways during the past year. A total of 141½ miles are now open for the public traffic in the colony, consisting of fifty-eight miles of the main line from Capetown to Wellington, sixty-four miles of the Ceres-road and Worcester Railway, six miles of the Wynberg branch line and thirteen and a-quarter miles of loop line from D'Urban road to Moulders Vley. The total capital expenditure on the open railways of the Western system to December 31st, 1876 was £1,259,313. During the year 620513 passengers were carried (irrespective of season-ticket holders), against 581,349 in 1875, the average fare being 1s. 7d. against 1s. 4d. in 1875. A total of 97,206 tons of goods were carried, against 89,521 tons in 1875, the average charge per ton being 13s. 0½d. in 1875 against 12s. 9½d. in 1876. A total of 279,737 miles were run during the year, at a cost of 5s. 1d. per train mile, as compared with 5s. 7½d. in 1875, and 6s. 2½d. in 1874. No fatal accidents occurred to any passengers. The report of the eastern district shows that at the end of 1876 a total of sixty-seven miles of railway were open severally between Port Elizabeth and Sand Flats, and between Zwaartkops Junction and Uitenhage. The working expenses of these lines averaged nearly 6s. 3½d. per train mile, but as yet, owing to the limited lengths open for traffic, the railway has hitherto been unable to compete with the ox-wagon. A line is also in process of construc-

tion between East London and King William's Town, a distance of ninety miles, at a cost up to the present time of £805,923. A total of from 1300 to 2500 men have been employed on this line, of which from 800 to 1850 were natives, 103 artisans, and seventy-two navvies who had been imported from Europe in 1876, making a total of 587 men of these classes engaged since the commencement of the work. A total length of fifty-six miles is now opened for passenger traffic in this district.—*Engineer*.

### ENGINEERING STRUCTURES.

**THE EAST RIVER BRIDGE.**—At a meeting of the trustees on the 4th of March, Chief Engineer W. A. Roebling reported upon a method of passenger transit, showing that the original plan of the Bridge contemplated three sidewalks, two railroad tracks, and two single wagon tracks. The great exposure to the weather and the great length of the bridge, however, caused the Chief Engineer to decide that three sidewalks were unnecessary; two were accordingly abolished, and by widening the whole bridge five feet, two more wagon tracks were added, so that the bridge will have two double tracks, each eighteen feet and seven inches in width, for vehicles; two railroad tracks, each thirteen feet in width; and a central promenade for pedestrians, also thirteen feet in width.

The railroad trains will be attached to an endless wire rope, to be propelled by a stationary engine on the Brooklyn side. It was estimated by the late John A. Roebling that a speed of twenty miles an hour, which could be increased to thirty or even forty miles, would be perfectly safe. The cars will be fifty feet in length, and capable of seating 100 persons comfortably. The doors will be on the sides. Passengers will pay their fares at a toll house before entering the cars. The cars are to be built of iron and steel. No flooring is to be laid under the tracks, in order to prevent obstruction from snow, but there will be an iron grating to prevent persons from falling through. The stretching of the cables is being steadily prosecuted, and the great revolving wheels, which pay out the wires two at a time, are the daily objects of attraction to the numerous passengers by the ferry boats.

**IRON BUILDING.**—An iron structure has just been erected for the Youngstown Rolling Mill Company, at Youngstown, O. The company determined to replace their rolling mill with a building of iron, and plans and bids were tendered by several prominent firms. The plans and specifications furnished by Mr. Alexander E. Brown, C.E., of Cleveland, were approved, and a contract made with him for the structure throughout and complete. The finishing work was done, and the building turned over to the owners on the last day of December, and was accepted as in every respect satisfactory. Practical mill men, pronounce it one of the best, if not the very best building of the kind in the Western country, and give much credit to the young contractor

for the excellence of the design and workmanship.

As most of the machinery is driven by belts, a very stiff frame is required to carry the lines of shafting and heavy pulleys. The strain upon every post, beam, rod and rafter in the complicated map of framework was carefully calculated, and proportioned with a strength of four times the actual strain, to be borne by it—in other words, with a factor of safety of four. The building is 140 feet long by 160 feet wide, the roof bridge being about 47 feet above the stone foundations, and consists of a central building 100 feet wide with a shed on each side thirty feet wide, the whole supported upon forty iron posts; those of the main or central part twenty-seven feet high. These columns are made of a combination of "T" rails, patented by Mr. Brown, and while they are equal if not superior in strength, are much less costly than those made with the column irons generally used. The entire roof and sides, to within eight feet of the ground, are covered with heavy corrugated iron, riveted to the frame, and thoroughly painted.

A ventilator runs the entire length of the roof at the ridge, and light is admitted through two skylights eight by seventeen feet in the main roof, and through a row of windows under the eaves of the main or central building, and above the roof of the sheds, and also under the eaves of the sheds and at the ends of the building. Not a foot of timber or wood was used in the construction of this building, and its cost will soon be reimbursed to its owners by the saving of all cost for insurance.—*Cleveland Journal*.

**THE ST. GOTHARD TUNNEL.**—Up to the first of the last month, 321,108 feet of the St. Gothard Tunnel had been perforated, 16,800 feet at the north (Goeschenen) end, and 15,308 feet at the south (Airolo) end. At present the work is rendered very difficult. On the north side for the last three months the borings have passed through serpentine, and on the south side through broken rock, which has required the greatest possible precaution to deal with. The mean progress has not lately exceeded thirteen feet per day.

### ORDNANCE AND NAVAL.

**TWO NEW IRONCLADS.**—The British Government has added two powerful war vessels to the navy of Great Britain by the acquirement of the ironclad *Payki-Sherref*, lately in Millwall Dock, and her sister ship, at present unnamed, and on the stocks at the adjacent building yard of Messrs. Samuda, nearly opposite Greenwich. The *Payki-Sherref*, which the Lords of the Admiralty recognise at present only by the title of "B 71," is finished, and furnished ready for sea, and the other ship is proposed to be like her in every respect. Technically speaking, the *Payki-Sherref* is an iron armor-cased corvette, with a raised fighting battery deck amidships. The battery deck rises from below the water line to a height of about 18 feet, and mounts four 25-ton

guns 12-inch muzzle-loaders, which are already on board, having been provided by Sir Wm. Armstrong when the ship was built for the Turkish Government, more than a year since, and detained as contraband of war. Two of the guns fight on the port and two on the starboard side, each pair being provided with gun-metal racers, giving them such scope for traversing that they can fire direct fore and aft, or combine upon one spot at 90 yards range. There is ample room to work the guns, the battery deck being an octagon of about 60 feet, while the guns, which are somewhat short in the chase, are 16 feet in length. They are rifled with eight grooves, and on an increasing twist. The projectiles as well as the guns are already on board, consisting of 650 12-inch shot and shell for the big guns, and some 200 for the 9-pounder guns, which will probably be mounted in the bows and astern. The larger projectiles comprise 240 chilled shells, on the Palliser principle, 100 chilled shot, 240 common shell, 70 shrapnel, and 170 segment shells. The armor plating consists of a belt of 12-inch iron at the water-line, diminishing above and below to 8 inches, the thickness of iron protecting the battery varying from  $9\frac{1}{2}$  to  $10\frac{1}{2}$  inches. The main deck, which will be nearly level with the water, is composed of 3 inch plates of armor, encased in oak. The designer of the ship was Hemit Pacha, of the Turkish navy, and for her length she is remarkably spacious. She measures between perpendiculars 245 feet, and has a breadth of nearly 60 feet even at a few feet from the stem and stern. Her burden in tons is 3075, builder's measurement, and her draught of water 19 feet forward and 19 feet 6 inches aft. Her displacement at the load-line is 4777 feet, and the area of her midship section 895.68 square feet. She is propelled by a pair of engines constructed by Messrs. Maudslay & Field, having a nominal horse-power of 600 and 3900 indicated. The guaranteed speed is twelve knots an hour. There is a steam steering apparatus and wheels to be worked by hand, both on the battery deck and under cover of the lower deck, and provision is made to cook for 350 men, while thirteen tanks are on board to contain 8000 gallons of water. The *Payki Sherref* is to undergo some slight alterations, which will be executed at Sheerness Dockyard. The other ship, now building, can be completed in a few months, and will be brought forward with all speed. Both ships have been surveyed and approved of by the Lords of the Admiralty.

**THE JAPANESE IRONCLADS.**—The three war-ships building in England for the Imperial Japanese Government from the designs of Mr. E. J. Reed have now all been tried under steam, and are expected to sail for Japan in the course of the next few weeks. The official speed trials have given very satisfactory results. The *Foo-so*, an iron vessel, 220 feet long and 48 feet extreme breadth, plated with 9 inch of armor, was tried upon the measured mile at the Maplin Sands on the 3rd inst. She has eight cylindrical boilers each 11 feet 3 inches in diameter, working at 60 pounds pressure,

and two pairs of Messrs. Penn's horizontal compound trunk engines driving twin screws, 15 feet 6 inches in diameter, with a pitch of 16 feet. The cylinders are 58 inches and 88 inches in diameter with 30 inch-trunks, and the stroke is 30 inches. Her draught was 17 feet 1 inch forward and 18 feet 1 inch aft, the immersed area of midship section was 788 square feet and the displacement 3639 tons. The vessel was under way  $8\frac{1}{2}$  hours in all, and steamed at full speed without stopping for about three hours. Six runs were made upon the mile, which resulted in a mean speed of 13.16 knots per hour with an indicated horse power of 3824. The estimated speed was 13 knots. The number of revolutions made was from 93 to 94. A steady pressure of 59 pounds per square inch was kept in the boilers during the trial, and in both condensers the vacuum was 27 inches.

The *Foo-so* showed excellent maneuvering powers, answering quickly to the action of the helm, turning in a very small circle. The engines worked very smoothly and satisfactorily. The builders of the ship are Messrs. Samuda Brothers of Poplar.

The *Kon-go*, a composite corvette of 231 feet in length, 40 feet 9 inches extreme breadth, and 17 feet 6 inches draught of water, built and engined by Earle's Shipbuilding and Engineering Company (Limited), of Hull, made her official speed trials off the mouth of the Humber on the 7th of December last. The engines are horizontal compound with return connecting rods. The cylinders are 60 inches and 99 inches diameter, and the stroke 33 inches. They are constructed to work with a boiler pressure of 60 pounds and to indicate 2500 horse power. The screw propeller is 16 feet in diameter with a pitch of 17 feet 6 inches. In the notice we gave of these ships on the 16th of November we said, that the speed expected of the *Kon-go* and her sister ship the *Hi-yei*, to be noticed presently, was  $13\frac{1}{2}$  knots, but that judging from the beauty of their lines and the magnitude of the engine power it was not unlikely that that estimate would be considerably exceeded.

Six runs were made by the *Kon-go* over a measured mile at Withernsea, which is on the Yorkshire coast a few miles north of Spurn Head, with the following results. The steam pressure was kept steadily at 60 pounds and 61 pounds per square inch in the boilers; the vacuum was  $25\frac{1}{2}$  inches, and the revolutions increased during the trial from 82 at the commencement to 87 at the close. The power indicated was 2450. The mean of the six runs was  $13\frac{3}{4}$  knots, but each pair of runs was so much better than those which preceded it, that if the day had been longer so as to have enabled one or two more pairs of runs to be made, the means of the last six runs would, in the opinion of Mr. Reed and the engineers on board, have reached 16 knots.

The remaining vessel, the *Hi-yei*, a sister ship to the *Kon-go*, built by the Milford Haven Shipbuilding and Engineering Company (Limited) at their works at Pembroke Dock, South Wales, and engined by the engineers of the *Kon-go*, made her official speed trials on the

26th ult. off Cardiff. The distance upon which she was run was bounded by a buoy and a lightship, and measurements taken upon a chart showed that the mean of four runs gave a speed of about  $14\frac{1}{2}$  knots per hour. A patent log that was left out during the whole time the vessel was running, and which would show less than the true speed owing to the loss that would take place in turning at the end of each run, indicated a speed of 13.915 knots per hour. This would show that the Hi-yei considerably exceeded 14 knots, and that the class of vessels she represents are able to do a good 14 knots per hour over the measured mile. The trial of the Kon-go points to the same result, as there was every appearance of reaching 14 knots with her if there had been sufficient day-light to have kept running her. The performance of the engines was considered highly satisfactory and an indicated horse power of 2490 was obtained.

The trials of these vessels have been made under the personal directions of Mr. E. J. Reed, and in the presence of His Excellency the Japanese Minister and suite.

### BOOK NOTICES

**THE ANEROID, ITS CONSTRUCTION AND USE.** Science Series No. 35. New York: D. Van Nostrand. Price 50 cts.

This little manual is designed for those who desire to apply the Aneroid to its legitimate use of measuring altitudes.

The late improvements in the manufacture of this instrument have rendered it as reliable in careful hands as the mercurial barometer, while it is infinitely more portable.

The book is compiled from the latest reliable sources, and affords short formulas for such approximate results as will satisfy the tourist as well as the most complete formulas and tables for the use of engineers.

For reconnaissance surveys the Aneroid safely replaces the level, and is rapidly coming into use for such purposes.

The principal tables in the book are those of Prof. Airy derived from his formula, and a table of five place logarithms for the application of La Place's formula.

The practical part of the book is preceded by a treatise of atmospheric pressure and the use of the Barometer in weather observations.

A portion of the book has appeared in this Magazine.

**BUILDING CONSTRUCTION.** By R. SCOTT BURN. London: William Collins, Sons & Co. For sale by D. Van Nostrand. Price \$3.00.

This is a new book by a well known author on kindred subjects, and is designed as a convenient manual for the designer of structures of different kinds, and embracing the use of timber, lead and iron.

The four parts treat respectively of Carpentry, Joinery, Iron, Lead and Zinc Work, and Miscellaneous Roof Coverings, Staircases, Strains.

The text book is illustrated by 480 cuts interspersed, and is accompanied by an Atlas of 60 plates.

**WEATHER WARNINGS AND WATCHERS. By "THE CLERK" HIMSELF.** London: Houlston & Sons. For sale by D. Van Nostrand. Price 50 cts.

The title of this book is pretentious and misleading. It is but little more than a thin treatise on instruments used in Meteorology, well illustrated.

**THE YEAR-BOOK OF FACTS IN SCIENCE AND ART.** By JAMES MASON. London: Ward, Lock & Co. For sale by D. Van Nostrand. Price \$1.25.

This contains apparently less matter than usual, but presents the same variety as ever. Entomology has its full share of attention, the only illustration being a magnified Colorado beetle.

**GEOLOGICAL SURVEY OF NEW JERSEY.** By GEO. H. COOK, State Geologist. Trenton: Noar, Day & Noar, Printers.

The present report relates to the clay deposits of New Jersey, and their uses for fire brick, pottery, etc. Like its predecessors it is a valuable addition to the literature of economic geology. The analyses of the various clays are given and their locations fully described both by topographical charts and by vertical sections.

The maps are exceedingly good. The report covers 380 octavo pages.

**MISCELLANEOUS PAPERS ON PHYSICAL SCIENCE.** By HUMPHREY LLOYD, D. C. L. London: Longmans, Green & Co. For sale by D. Van Nostrand. Price \$6.40.

The author of these papers, now Provost of Trinity College, Dublin, was formerly Professor of Natural Philosophy in that university.

The papers, twenty-three in number, embrace subjects relating to Optics, Meteorology, and Terrestrial Magnetism, especially the latter.

It is a well printed, royal octavo of 510 pages, with a few illustrations, including a finely engraved magnetic chart of Ireland.

**THERMODYNAMICS.** By P. G. TAIT, M. A. Second Edition. Edinburgh: David Douglas. For sale by D. Van Nostrand. Price \$2.50.

This new edition comes in an excellent typographical dress, which is eminently fitting to a treatise every page of which threatens the reader with a headache unless he is fresh in his mathematics.

Prof. Tait is an acknowledged master of the higher analyses and especially in the line of physical research.

**REPORT ON THE IRON MANUFACTURE OF THE UNITED STATES OF AMERICA.** By I. LOWTHIAN BELL, Esq., F. R. S. London: Eyre & Spottiswoode. For sale by D. Van Nostrand. Price 60 cts.

The substance of this pamphlet has already appeared in our pages. It presents in the most satisfactory manner a comparison of the methods of manufacture of iron and steel in this country with that of Great Britain, and will always be a valuable record because prepared from personal observation by the person best qualified to do it.

**A MANUAL OF ENGINEERING SPECIFICATIONS AND CONTRACTS.** By Prof. LEWIS M. HAUPT. Philadelphia: J. M. Stoddart & Co. For sale by D. Van Nostrand. Price \$3 00.

This is an instructive manual of an uncommon kind, but of the highest importance to the young engineer. It covers that branch of engineering education which can be satisfactorily learned from a book without other aid. Even experienced engineers cannot afford to trust to memory alone in drawing specifications, and will find a carefully prepared book of valuable service.

The topics treated by chapters are as follows: Chapter 1, Drawings; Chap. 2, Estimates and Measurements; Chap. 3, Specifications; Chap. 4, Advertisements; Chap. 5, Bids or Proposals; Chap. 6, Contracts.

Numerous illustrative examples are given, the whole covering something over 300 octavo pages.

**THE ROYAL NAVY LIST**, containing Dates of all Commissions, &c., and a Statement of the War and Meritorious Services, Medals, Decorations, Honors, &c., of the Officers of the Royal Navy and Royal Marines on the Active and Retired Lists. By C. E. WARREN, R. N., and Lieut.-Colonel F. LEAN, R. M. L. I. January, 1878. London: Witherby & Co. For sale by D. Van Nostrand. Price \$3.00.

This is a new quarterly. The following is from the *Army and Navy*:

"The Naval Service is to be congratulated on the appearance of this much-required work, and the Editors deserve every support for the enterprise they have shown in undertaking the great labor and cost of publication. The scope of the List will be recognized when we state that it contains all that is to be found in the quarterly official 'Navy List,' together with the following important additions. The dates of all commissions held by an officer are given, so that the rapidity, or otherwise, of his progress can be seen at a glance, while by foot-notes on each page reference is made to any special causes of promotion. The War and Meritorious Services of Officers of all grades are given in another part of the book, and this portion of the List will be made a most valuable record if officers themselves will give the Editors the assistance they ask and forward particulars of their services. There are also recorded the deeds by which the Victoria Cross, Albert Medal, the Awards of the Humane Society, and other institutions have been won. The type is excellent, and the system upon which the names have been arranged and references are given in the different lists make the work of tracing an officer's career quite easy, instead of being a labor. Next quarter the List will be enlarged, owing to additional information being received from a variety of sources, and the price will have to be raised to meet the increased cost of production; but we feel sure that the Service will appreciate the appearance of this Naval 'Hart,' and will not allow it to suffer from any want of support."

**THE PATTERN MAKER'S ASSISTANT**, embracing Lathe Work, Branch Work, Core Work, Sweep Work and Practical Gear Con-

struction. By JOSHUA L. ROSE, M. E. New York: D. Van Nostrand. Price \$2.50.

The author of this practical treatise is well-known on both sides of the Atlantic, through his contributions to technical journals upon tools and their use.

The collected papers form a work entitled "The Complete Practical Mechanic," a work of the most thoroughly practical character.

The present work is illustrated with 244 cuts, and besides a large collection of valuable tables presents the following topics:

Contents: Chapter I, General Remarks; Selection of Wood; Warping of Wood; Drying of Wood; Plane-irons; Grinding Plane irons; Descriptions of Planes; Chisels; Gouges; Compasses; Squares; Gages; Trammels; Winding-strips; Screw-driver; Mallet; Calipers. Chap. II, Lathe; Lathe Hand-rest; Lathe Head; Lathe Tail-stock; Lathe Fork; Lathe Chucks; Gouge; Skew-chisel; Turning Tools. Chap. III, Molding Flask; How a Pattern is Molded; Snap Flask. Chap. IV, Description of Cores; Core boxes; Examples of Cores; Swept Cores for Pipes, etc. Chap. V, Solid Gland Pattern; Molding Solid Gland Pattern; Gland-pattern without Core-print; Gland Pattern made in Halves; Bearing or Brass Pattern; Rapping Patterns; Example in Turning; Sand-papery; Pattern Pegs; Pattern Dog or Staple; Varnishing; Hexagon Gage; Scriber. Chap. VI, Example in T-joints, or Branch Pipes; Example in Angular Branch Pipes; Core Box for Branch Pipes. Chap. VII, Double-flanged Pulley; Molding Double-flange Pulley; Building up Patterns; Shooting-board; Jointing Spokes. Chap. VIII, Pipe Bend; Core-box for Pipe Bend; Swept Core for Pipe Bend; Staving or Lagging; Lagging Steam Pipes. Chap. IX, Globe Valve; Chucking Globe Valve; Core-boxes for Globe Valve. Chap. X, Bench-aid; Bench-stop; Bench-hook; Mortise and Tenon; Half-lap Joint; Dovetail Joint; Mitre Box; Pillow Block. Chap. XI, Square Column; Block for Square Column; Ornaments for Square Column; Cores for Square Columns; Patterns for Round Columns. Chap. XII, Thin Work; Window Sill; Blocks for Window Sill. Chap. XIII, Sweep and Loam Work; Sweeping up a Boiler; Sweep Spindle; Sweeping up an Engine Cylinder. Chap. XIV, Gear-wheels; Construction of Pinion; Construction of Wheel-teeth; Gage for Wheel-teeth; Bevel Wheels; Building-up Bevel-wheels; Worm Patterns; Turning Screw of Worm Pattern; Cutting Worm by Hand; Wheel Scale. Chap. XV, Patterns for Pulleys; Section Patterns. Chap. XVI, Cogging; Wood used for Cogging; Templates for Cog-Teeth; Sawing out Cogged Teeth; Boring Cogged Teeth; Chap. XVII, Machine Tools for Pattern Making; Face Lathe; Jig Saw; Band Saw; Circular Saw; Planing Machine; Glue Pot. Chap. XVIII, Shrinkage of Solid Cylinders; Shrinkage of Globes; Shrinkage of Disks; Shrinkage of Round Square Bars; Shrinkage of Rectangular Tubes; Shrinkage of U-shaped Castings; Shrinkage of Wedge-shaped Castings; Shrinkage of Ribs on Plates; General Laws of Shrinkage; Table of Shrinkage; Calculating Thickness of Thin Pipes; Calculating Thickness of Cylinders.

ders for Hydraulic Presses; Calculating Rims of Fly-wheels.

**CORRECTION.**—The reviewer of Du Bois' "Graphical Statics" writes that he was in error in stating (on p. 191) that "the kernel of Fig. 37, plate II. is wrong side up." But it should be added that Du Bois makes a mistake in connection with the discussion of this figure, for the note at the bottom of page 77 should be corrected by multiplying both members of the first equation by  $\sin. \phi$ .

### MISCELLANEOUS.

**MESSERS. SMITH, FASSETT & Co.,** of Tonawanda, N. Y., report having shipped the past season over 70,000,000 feet of lumber, besides a proportionate quantity of shingles, lath, etc., an increase of almost 100 per cent. over their business of last year. They deal exclusively in Michigan pine, which is shipped from their docks to customers in New York, Pennsylvania, Maryland, and sections still further east. Their facilities for handling lumber are such as to enable them to manipulate their stock easily and economically. They have a dock frontage of 2,700 feet and storage room for an ample supply of everything which it is necessary for them to sell. The rapid growth of the business represented by this firm is no doubt due in a great measure to the practical knowledge of the trade possessed by each of its members.

**I**T is very well known that if the air in sewers could be kept in continual motion in one direction, so that no stagnation could take place, the danger attending the development of sewer gases would be avoided. To this end vertical shafts have been proposed and tried without success, for causing the upward current of the sewer gas or air. Similar shafts are now proposed by Mr. R. Parker, surveyor to the Board of Works for the Poplar district, but in place of using them as uptakes he provides their upper ends with a cowl, the opening of which is always presented to the wind which enters the sewers and keeps up a current that constantly changes the gaseous contents of the sewer by driving them out at every opening. Mr. Parker proposes to use "a number of cast iron shafts erected about 12 feet high and 10 inches diameter, in convenient and open places, and also pipes of various sizes according to circumstances, from the sewers and existing drains at the rear of houses, to the house top as high as the chimney stack, and these pipes or ventilating shafts should be surmounted by a cowl, guided by a vane attached to it, so that its opening or aperture shall always be facing the wind. The air or wind impinging upon it will force down the air within it, and pass into the sewer and travel along it, entering all drains and ramifications to find an outlet so that it may escape. The air within the sewer requires very little force to cause it to move forward, as it has in itself a tendency to move upwards." He has made some experiments which are described in a recent report to the Poplar Board, "to see if the force of the wind

and air could be conducted into the sewers, in this way to force out the gases and keep up a constant current of fresh air; it has been found that there was always a downward current in the ventilating shaft, and an upward rush of pure air in all the gulleys and drains in its immediate neighborhood." A shaft was constructed from a drain to the roof of a house in Bow, the distance from the cowl to the sewer being 13 feet. The average results of the first seven experiments gave:—Temperature outside sewer, 43.28 deg.; temperature inside sewer, 48.86 deg.; velocity of wind outside sewer, 4.61 miles per hour; velocity of wind at junction of 9 inches drain in sewer, 1.81 miles per hour. Cubic feet of air forced into sewer per hour, 4210.

**THE FALL OF A MOUNTAIN IN SAVOY.**—An interesting account of the recent falling of a mountain in Tarentaise, Savoy, causing disaster to two flourishing villages, has been communicated to the *Courrier des Alpes*, by M. Bérard. The phenomenon has been incorrectly reported as instantaneous and the destructive effect complete, whereas the case is that of a mountain which for twenty days, without cessation, has been dismembering itself and literally falling, night and day, into the valley below, filling it with piled-up blocks of stone, extinguishing all sounds by its incessant thunder, and covering the distant horizon with a thick cloud of yellowish dust. The entire mass comprised in the slope forms a mutilated cone 200 meters broad at the top and 600 at the base (the slope being about 50 degrees); this is composed of hard schist lying close together, but no longer united; and it is united to the body of the mountain only by a vertical mass of 40 or 50 meters thick, which is already fissured and shaken. Periods of repose occur, lasting only a few seconds; or a minute at most; then the movement recommences and continues about 500 hours. Blocks of 40 cubic meters become displaced with no apparent cause, traverse the 1,800 meters of descent in thirty seconds, leaping 400 or 500 meters at a time, and finally get dashed to pieces in the bed of the torrent, or launch their shattered fragments into the opposite forest, mowing down gigantic pines as if they were so may thistles. One such block was seen to strike a fine fir-tree before reaching the bridge between the villages; the tree was not simply broken or overthrown, but was crushed to dust (*volatilisé*); trunk and branches disappeared in the air like a burning match. Rocks are hurled together and broken into fragments that are thrown across the valley like sparrows in a whirlwind; then follow showers of smaller fragments, and one hears the whistling sound of thousands of pebbles as they pass. M. Bérard reached the edge of the rock (2,460 meters high) on one of the sides of the falling cone, and ventured along it obtaining a good view of the "terifying" spectacle. He reaffirms his conviction that the phenomenon is inexplicable by any of the usual reasons that account for Alpine disturbances, such as penetration of water or melting of snows, or inferior strata in motion; nor does the declivity of the slope explain it.—*Nature*.

# VAN NOSTRAND'S

## ECLECTIC

# ENGINEERING MAGAZINE.

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### A NEW GENERAL METHOD IN GRAPHICAL STATICS.

BY HENRY T. EDDY, C. E., Ph. D., University of Cincinnati.

Written for VAN NOSTRAND'S MAGAZINE.

V.

#### UNIFORMLY VARYING STRESS IN GENERAL.

The methods employed in Figs. 13 and 14 are applicable also to any uniformly varying stress, for a stress which uniformly increases from any neutral axis  $x$  through the center of gravity of the cross section can be changed into a stress which uniformly increases from same parallel axis  $x'$  at a distance  $y_0$  from  $x$  by simply combining with the former a stress uniformly distributed over the cross-section and of such intensity as to make the resultant intensity zero along  $x'$ .

In the construction given in Figs. 13 and 14 it is only necessary to use the proposed line  $x'$  at a distance  $y_0$  from  $o$ , instead of the tangent to the extreme fiber at a distance  $y_1$  or  $y_2$  from  $o$ , when we wish to determine the weight or volume of the resultant stress solid, its moment about  $o$ , and its center of gravity or application.

Since the locus of the center of application of the resultant stress is the anti-pole of  $x'$  with respect to the ellipse of inertia, it is evident that when the proposed axis  $x'$  lies partly within the cross section the center of application of the resultant stress is without the kernel, and that when  $x'$  is entirely without the

cross section its center of application is within the kernel.

It is frequently more convenient to determine the center of application from the kernel itself than from the ellipse of inertia. This can be readily found from the equation which we are now to state

$$Ar_0y_0 = Ar_1y_1 = I,$$

in which equation  $Ay_0$  and  $Ay_1$  are the volumes of the stress solids which if uniformly distributed and compounded with the stress whose neutral axis is  $x$ , will cause the resultant stresses to vanish at distances  $y_0$  and  $y_1$ , respectively; while  $r_0$  and  $r_1$  are the distances from  $o$  of the respective centers of application of these stresses.

The truth of the equation is evident from the fact that the moment about  $o$  of any stress solid uniformly distributed is zero, hence the composition of such a stress with that previously acting will leave its moment unchanged.

From the equation just stated we have

$$y_0 : y_1 :: r_1 : r_0,$$

from which  $r_0$  can be found by an elementary construction, since  $y_0$ ,  $y_1$  and  $r_1$  are known quantities. When it is de-

sired to express these results in terms of the intensities of the actual stresses,

let  $p_0 = ny_0$  be the mean stress;  
and let  $p_1' = n(y_0 + y_1)$  be the greatest,  
and let  $p_2' = n(y_0 - y_2)$  be the least  
intensity at the extreme fiber:

$$\text{then } ny_1 = p_1' - ny_0 = p_1' - p_0$$

$$\text{or } ny_2 = ny_0 - p_2' = p_0 - p_2'$$

$$\therefore p_0 : p_1' - p_0 :: r_1 : r_0$$

$$\text{or } p_0 : p_0 - p_2' :: r_2 : r_0$$

in which  $r_1$  and  $r_2$  are the two radii of the kernel.

#### DISTRIBUTION OF SHEARING STRESS.

It is well known that the equation  $dM = Tdz$ , expresses the relation of the total shearing stress  $T$  sustained at any cross section of a girder to the variation  $dM$  of the bending moment  $M$  at a parallel cross-section situated at the small distance  $dz$  from the first mentioned cross section.

We have already treated the normal components of the stress caused by the bending moment  $M$ : we shall now treat the tangential component or shear which accompanies any variation of the bending moment.

We shall assume as already proved the following equation\* which expresses the intensity  $q$  of the shearing stress at any point of the cross section:

$$Iqx = TV$$

in which  $x$  is the width of the girder measured parallel to the neutral axis at any distance  $y$  from the neutral axis, and  $q$  is the intensity of the shearing stress at the same distance,  $I$  is the moment of inertia of the cross section about the neutral axis,  $T$  is the total shear at this cross section, and  $V$  is the volume of that part of one of the stress solids used in finding the moment of inertia which is situated at a greater distance than  $y$  from the neutral axis, *i.e.* in Fig. 13 if we were finding the value of  $q$  at  $b_2$ , with respect to  $om_2$  as the neutral axis, then  $V$  would signify the stress solid whose profile is  $d_1d_2b_2b_1$ . It, however, makes no difference whether we define  $V$  as the stress solid situated at the left or at the right of  $b_2$ ; for, since the total

stress solid, positive and negative, is zero, that on either side of any assumed plane is the same.

The first step in our process is to find the intensity of the shear at the neutral axis, which we denote by  $q_0$ ; and if we also call  $x_0$  the width here and  $V_0$  the volume of either of the two equal stress solids between this axis and the extreme fiber, we have

$$Iq_0x_0 = TV_0, \text{ but } I = V_0d$$

when  $d$  is the distance between the centers of application of the equal stress solids, *i.e.*,  $d$  is the arm of the couple of the resultant stresses. Also  $T = A\bar{q}$  when  $A$  is the total area of the cross section and  $\bar{q}$  is the mean intensity of the shearing stress. Hence at the neutral axis we have the equation

$$q_0x_0d = A\bar{q}T$$

Now the length of the arm  $d$  is found in Fig. 13 by prolonging the middle side (*i.e.* the side through  $n_3$ ) of the second equilibrium polygon until it intersects the first side and the last. These intersections will give the position of the centers of gravity of the stress solids on either side of  $o$ .

In Fig. 14 the same points are found by drawing rays from  $v$  parallel respectively to  $z_1f_0$  and  $f_1f_0$  until they intersect  $aa$ .

In Fig. 15 the points  $f_1$  and  $f_2$  are found by either of these methods and  $f_1f_2 = d$  is the required distance.

Now in Fig. 15 let the segments  $uu$  of the summation polygon be obtained just as in Fig. 14, and parallel to  $uu$  draw a line through  $s$  representing the width of the cross section  $x_0$  on the same scale as before used in constructing the summation polygon. Also make  $su_1 \parallel cf_1$  and  $su_2 \parallel cf_2$ ,  $c$  being the common point in the rays of the pencil of the summation polygon for finding the area.

Then  $uu_1$  represents the product  $x_0d$  on same scale that  $u_1u_2$  represents  $A$ . Now draw from any point  $i$  rays to  $u_1$ ,  $u$  and  $u_2$ , and also a parallel to  $iu_1$  at a distance  $\bar{q}$  and intersecting  $iu$  at some point  $t_0$  such that  $tt_0 = \bar{q}$  to such a scale as may be convenient. The mean intensity  $\bar{q}$  is supposed to be a known quantity

\* See Rankine's Applied Mechanics. Eighth Edition, Art. 309, p. 338.

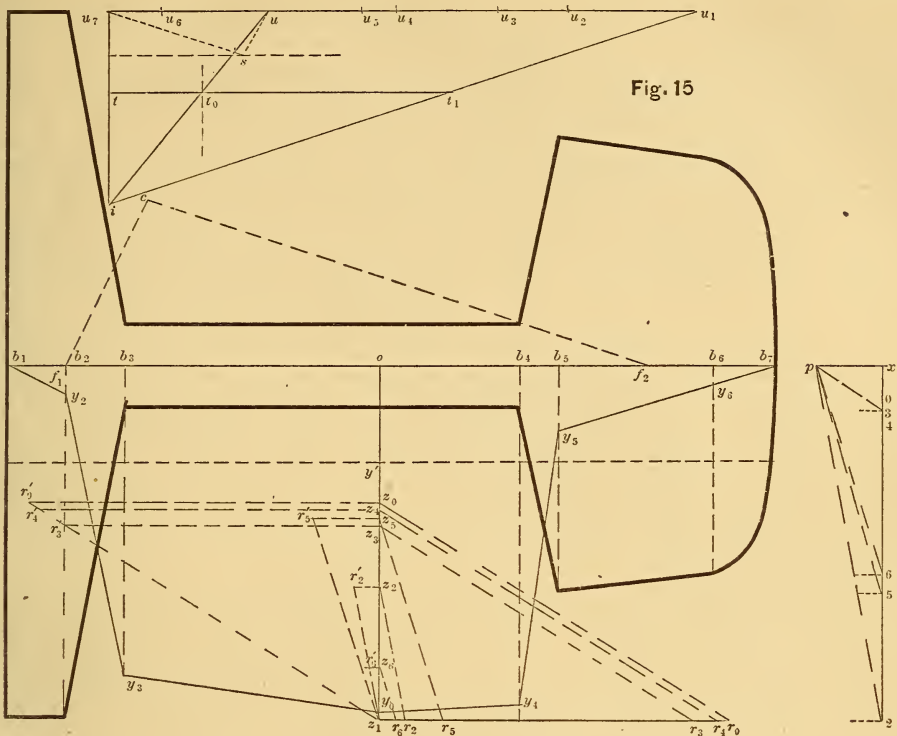


Fig. 15

ty, and  $tt_0 \parallel uu$ . Then from the proposed equation we have the proportion

$$x_0 d : A :: \bar{q} : q_0$$

or  $uu_7 : u_1 u_7 :: tt_0 : tt_1$

Hence  $tt_1$  represents the intensity of the shearing stress at the neutral axis on the same scale that  $tt_0$  represents the mean intensity.

This first step of our process has determined the intensity of the stress at the neutral axis relatively to the mean stress; the second step will determine the intensity of the stress at any other point relatively to the stress at the neutral axis. When this last point is all that is desired the first step may be omitted.

The equation  $Ixq = TV$  may be written  $xq = cV$ , in which  $c = T \div V$  is a constant. At the neutral axis this equation is

$$x_0 q_0 = cV_0 \text{ or } V_0 : q_0 :: x_0 : c$$

In Fig. 15 lay off the segments of the line  $zz$  just as in Fig. 14; then  $z_1 z_0$  represents the weight or volume  $V_0$ ; also make  $x_0, x_2, x_3$ , etc., proportional to

width of the girder at  $o, b_2, b_3$ , etc., and lay off  $z_1 r_0 = z_0 r_0' = tt_1$ .

Draw  $p0 \parallel r_0 z_0$ , then by similar triangles

$$z_1 z_0 : z_1 r_0 :: x_0 : xp$$

or

$$V_0 : q_0 :: x_0 : c$$

$\therefore px$  represents the constant  $c$ .

Now the several segments  $z_1 z_2, z_1 z_3, z_1 z_4$ , etc., represent respectively the values of  $V_2, V_3, V_4$ , or the stress solids between one extreme fiber and  $b_2, b_3, b_4$ , etc.; it is of no consequence which extreme fiber is taken as the stress solid is the same in either case.

Now using  $p$  as a pole draw rays to 2 3 4 5 etc., and make  $z_2 r_2 \parallel p2, z_3 r_3 \parallel p3$ , etc., then by similar triangles

$$z_1 z_2 : z_1 r_2 :: x_2 : c, \text{ or } x_2 q_2 = cV_2$$

$$\text{and } z_1 z_3 : z_1 r_3 :: x_3 : c, \text{ or } x_3 q_3 = cV_3$$

etc., etc., and  $z_1 r_2, z_1 r_3$ , etc., represent the intensity of the shearing stresses at  $b_2, b_3$ , etc. These can be constructed equally well by drawing rays from  $z_1$  parallel to the rays at  $p$ , from which we obtain

$$z_2 r_2' = z_1 r_2, z_3 r_3' = z_1 r_3, \text{ etc.}$$

Now lay off  $b_2 y_2 = z_1 r_2$ ,  $b_3 y_3 = z_1 r_3$ , etc., then the ordinates  $by$  of the polygon  $yy$  represent the intensity of the shearing stress on the same scale that  $tt_1 = z_1 r_1$  represents the intensity  $q_0$  at the neutral axis, and on the same scale that  $tt_0 = oy'$  represents the mean intensity  $\bar{q}$ . The lines joining  $y_2$ ,  $y_3$ , etc., should be slightly curved, but when they are straight the representation is quite exact.

#### RELATIVE STRESSES.

It is proposed here to develop a new construction which will exhibit the relative magnitude of the normal components of the stresses produced by a given system of loading in the various cross-sections of a girder having a variable cross section. The value of such a construction is evident, as it shows graphically the weakest section, and investigates the fitness of the assumed disposition of the material for sustaining the given system of loading.

The constructions heretofore given for the kernel and moments of resistance at any given cross section admit of the immediate comparison of the normal components of the stresses produced in that single cross section when different neutral axes are assumed, but by this proposed construction, a comparison is effected between these stresses at any different cross sections of the same girder or truss.

In the equation previously used

$$M = SI \div y = S A k^2 \div y = S A r$$

in which  $M$  is the moment of flexure which produces the stress  $S$  in the extreme fiber of a cross section whose area is  $A$  and whose radius of resistance is  $r$ , we see, since the specific moment of resistance  $m = A r$  is the product of two factors, that the same product can result from other and very different factors.

For example, let  $m = A_0 r'$  in which  $A_0$  is the area of some cross section which is assumed as the standard of comparison, and  $r' = A r \div A_0 = a r$ , when  $a = A \div A_0$ . Then is  $A_0 r'$  the specific moment of resistance of a cross section of an assumed area  $A_0$  which has a different disposition of material from that whose specific moment of resistance is  $A r$ , but the

cross sections  $A$  and  $A_0$  are equivalent to each other in this sense, that they have the same specific resistance, and consequently the same bending moment will produce equal stresses in the extreme fiber in each.

The two cross sections do not have the same moment of inertia, and so the deflections of the girder would be changed by substituting one cross section for the other. We shall then speak of them as equivalent only in the former sense, and on the basis of this definition, state the result at which we have arrived thus: Equivalent cross sections under the action of the same bending moment, have the same stresses at the extreme fiber (though they are not equally stiff); hence in comparing stresses equivalent cross sections may be substituted for each other (but they may not be so substituted in comparing deflections).

It is proposed to utilize this result by substituting for any girder or truss having a variable cross section  $A$  or a variable specific moment of resistance whose magnitude is expressed by the variable quantity  $A r$ , a different one having a cross section everywhere of constant area  $A_0$ , but of such disposition of material that its specific moment of resistance is  $A_0 r' = A r$  at corresponding cross sections.

The proposed substitution is especially easy in case of a truss, for in it the value of  $r$  varies almost exactly as its depth, as may be seen when we compute the value of

$$m = A k^2 \div y = A r$$

in this case.

Since the material which resists bending is situated in the chords alone and is all approximately at the same distance from the neutral axis we have  $k^2 \div y = r = \frac{1}{2} h$  very nearly when  $h$  is the distance between the chords,  $\therefore m = \frac{1}{2} A h$  nearly. Even when the two chords are of unequal cross section and the neutral axis not midway between them the same result holds when the ratio of the two cross sections is constant.

In Fig. 16 let  $xx$  be the axis of a girder sustaining at the points  $x_1$ ,  $x_2$ , etc., the weights  $c_1 c_2$ ,  $c_2 c_3$ , etc. Lay off the ordinates  $xy$  at each of the points at which weights are applied, so that  $xy = A r$  on some assumed scale; then since

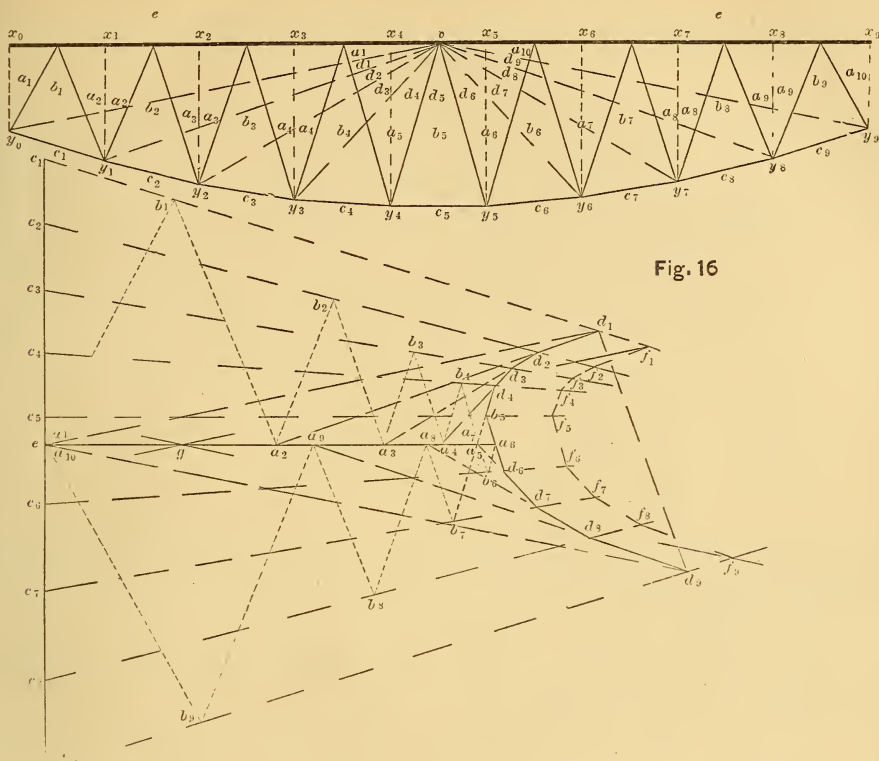


Fig. 16

$A_0 r' = Ar = xy$ ,  $xy$  varies as  $r'$ , the radius of resistance of a girder having at every point a cross section  $A_0$  so disposed as to be equivalent to that of the given girder  $xy$ .

Assume some form of framing connecting the points  $xy$  as shown in the Fig., and suppose the weights applied at the points  $yy$  of the lower chord, the points of support being at  $y_0$  and  $y_9$ . Then by a method like that employed in Fig. 3, we obtain the total stresses  $ea_2$ ,  $ea_3$ ,  $ea_4$ , etc., in the segments of the upper chord which are opposite to  $y_1, y_2, y_3$ , etc. Now these total stresses are resisted by a cross section of constant area  $A_0$ , consequently they have the same ratio to one another as the intensities per square unit; or further, they represent, as we have just shown, the relative intensities of the stresses on the extreme fiber of the given girder.

It is well known from mechanical considerations, that the stress in the several segments of the upper chord is dependent upon the loading and upon

the position of  $y_1, y_2$ , etc., and is not dependent upon the position of the joints in the upper chord. Of this fact we offer the following geometrical proof derived from the known relations between the frame and force polygons.

We know, if any joint of the upper chord, such as  $ea_2b_1$ , for example, be removed to a new position, such as  $v$ , that so long as the weights  $c_1c_2, c_2c_3$ , etc., are unchanged, that the vertex  $b_1$  of the triangle  $ea_2b_1$  in the force polygon must be found on the force line  $c_1f_1 \parallel y_0y_1$ . We shall show that while the side  $ea_2$  is unchanged, the locus of  $b_1$  is the force line  $c_1f_1$ ; hence conversely, so long as  $c_1f_1$  is the locus of  $b_1$ ,  $ea_2$  is unchanged, since there can be but one such triangle.

In Fig. 17 let the two triangles  $abe, hnk$ , have the sides meeting at  $b$  and  $n$  mutually parallel. Let the bases  $ae$  and  $hk$  be invariable but let the vertex  $b$  be removed to any point  $d$  such that  $bd \parallel hk$ , then will the vertex  $n$  be removed to a point  $m$  such that  $mn \parallel ae$ .

For, prolong  $ad$  and  $eb$ , and draw

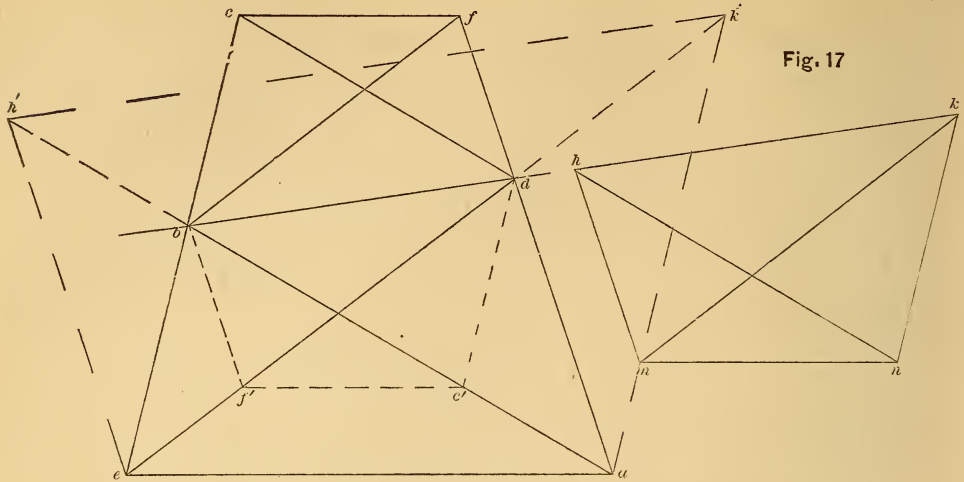


Fig. 17

$bf \parallel ed$  and  $dc \parallel ab$ , then is  $abfcdca$  a hexagon inscribed in the conic section consisting of the two lines  $af$  and  $ec$ , hence by Pascal's Theorem, the opposite diagonals  $ea$  and  $cf$  intersect on the same line as the remaining pairs of opposite diagonals,  $ab \parallel dc$  and  $ed \parallel bf$ . But this line is at infinity, hence  $cf \parallel ae$ . Also  $c'f' \parallel cf$ , from elementary considerations; and  $c'f' \parallel mn$  from similarity of figures, hence  $mn \parallel ae$ . There are two cases, according as  $mn$  is above or below  $hk$ , but we have proved them both.

Now in Fig. 16 let all the joints in the upper chord be removed to  $v$ , then the segments  $ea_2, a_2a_3$ , etc., are unchanged, hence  $ea_3, ea_4$ , etc. are unchanged, and the assumed framing reduces to the frame pencil whose vertex is  $v$ . The corresponding force polygon is the equilibrating polygon  $dd$ .

Hence the frame pencil can be used as the assumed framing just as well as any other form of framing, and it is unnecessary to use any construction except that of the frame pencil and equilibrating polygon for finding the relative stresses  $ea_2, ea_3$ , etc.

#### STRESSES IN A HORIZONTAL CHORD.

If Fig. 16 be regarded as representing an actual bridge truss, whose chords are not of uniform cross section; it is seen that the total stresses on the horizontal chord are given by the segments  $ea_2, ea_3$ ,

etc., which are found from the equilibrating polygon alone without regard to the kind of bracing in the truss, which it is unnecessary to consider; and this method can be used to take the place of that given in connection with Fig. 3 for finding the maximum stresses on the chords.

The equilibrating polygon  $ff$  was constructed to determine the reactions of the piers by finding the point  $e$ . The outer sides of the polygon  $ff$  intersect at  $g$  which determines  $e$  as explained in Fig. 7 in a manner different from that given in Fig. 3.

This construction sheds new light upon the significance of the frame pencil and equilibrating polygon. The frame pencil is the limiting case of a truss when the joints along one chord are removed to a single point, so that each ray may be regarded as compounded of a tension member and a compression member, having the same direction, *e.g.*, the tension member of which  $y, v$  is compounded has the stress  $d_1a_2$ , and the compression member the stress  $d_2a_2$ , but if the two be combined, the resultant tension is  $d_1d_2$ .

In case  $yy$  is the equilibrium curve due to the applied weights, and  $v$  falls upon the closing line, the force lines  $cd$  meet at the pole and the lines  $ed_1, ed_2$ , coincide with  $aa$ , so that the polygon  $dd$  is at the pole and infinitely small, and the stress in every segment of the upper chord is equal to the pole distance  $de$ .

## SUPPLEMENTARY NOTE TO THE "NEW CONSTRUCTIONS IN GRAPHICAL STATICS."\*

The truth of Proposition IV is, perhaps, not sufficiently established in the demonstration heretofore given. As it is a fundamental proposition in the graphical treatment of arches, and as it is desirable that no doubt exist as to its validity, we now offer a second proof of it, which, it is thought, avoids the difficulties of the former demonstration.

Prop. IV. If in any arch that equilibrium polygon (due to the weights) be constructed which has the same horizontal thrust as the arch actually exerts; and if its closing line be drawn from consideration of the conditions imposed by the supports, etc.; and if, furthermore, the curve of the arch itself be regarded as another equilibrium polygon due to some system of loading not given, and its closing line be also found from the same considerations respecting supports, etc.; then when these two polygons are so placed that their closing lines coincide, and their areas partially cover each other, the ordinates intercepted between these two polygons are proportional to the real bending moments acting in the arch.

The bending moments at every point of an arch are due to the applied forces and to the shape of the arch itself.

The applied forces are these: the vertical forces, which comprise the loading and the

vertical reactions of the piers; the horizontal thrust; and the bending moments at the piers, caused by the constraint at these points of support. The loading may cause all the other applied forces or it may not: in any case the bending moments are unaffected by the dependence or want of dependence of the thrust, etc., upon the loading.

Now, so far as the loading and the moments due to the constraint at the piers are concerned, they cause the same bending moments at any point of the arch as they would when applied to a straight girder of the same span, for neither are the forces nor their arms different in the two cases. But the horizontal thrust, which is the same at every point of the arch, causes a bending moment proportional to its arm, which is the distance of its line of application from the curve of the arch. This line of application is known to be the closing line; hence the ordinates which represent the bending moments due to the horizontal thrust, are included between the curve of the arch and a closing line drawn in such a manner as to fulfill the conditions imposed by the joints or kind of support at the piers.

But the same conditions fix the closing line of that equilibrium polygon which represents the bending moments due to the loading and to the constraint at the piers. Hence the resultant bending moment is found by taking the difference of the ordinates at each point, or by laying them off from one and the same closing line exactly as described in the statement of our proposition.

\* See Van Nostrand's Engineering Magazine, Vol. XVI.

## SPRINGS.

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Contributed to VAN NOSTRAND'S MAGAZINE.

### I.

IN this essay on Springs, I treat the subject by first giving a view of the materials, forms, sizes, uses and manufacture of springs, in general, and secondly, by taking up the Helical Spring in particular and in detail, and especially in its connection with India rubber: Rubber Springs are also considered by themselves.

The second part describes the means employed, the *modus operandi*, and the results of the tests of helical springs.

A SPRING MAY BE defined to be a medium, which, by reason of its elasti-

city, will yield, when actuated by a force, without detriment to the material of which it is manufactured or to the form in which it is employed.

Various devices are used to obtain such a medium, which are all dependent upon the elasticity of the substance used, or upon that and the special form which it is made to assume.

THE FORM should be so chosen as to give the required flexibility, with an easy, uniform, sensitive and elastic action, without abrasion. It should be compact in form, economizing space; of the least

weight allowable, economising first cost and locomotive power, if used in that connection; and should be so placed in connection with mechanisms as to be accessible at all times for examination, repairs, or replacement.

THE MATERIAL should be of a nature the least possible affected by the ordinary changes of temperature, and the best capable of enduring the wear and tear, to which it will naturally be subjected. It should moreover be, in the form of its manufacture and its fittings, of an appearance the least clumsy and uncouth, compatible with the nature of its uses.

#### MATERIAL.

The spring which resists by direct compression or extension, and is of the form of a solid block, generally consists of a material which admits of an appreciable distortion, before resisting considerably.

By experiment it has been found that India rubber, used in this shape will act very well for compression; but when attempted to be used as a tension organ, it soon loses its elasticity: for the other forms, metals, brass, steel, wood, compressed air, combined rubber and steel are used. The ancients made springs of bronze, containing three or four per cent. of tin (carriage springs were unknown among them).

In this country, for helical springs, cast steel and brass are used; brass is found advantageous for the reason that it does not necessitate any subsequent tempering, the brass being hardened by being sufficiently drawn without annealing; for flat brass springs, cold rolled sheet brass, which appears smooth and is rigid and glossy, is used.

#### FORMS.

Springs are familiar in many forms; we may have a solid piece which resists by direct compression or tension; a plate, plain or curved, which resists by flexion; a helix which resists by torsion; and gases have been used as elastic mediums. As examples, we have the rubber spring, the elliptic spring, the helical spring and the pneumatic spring.

Under each of the above-named heads there is a variety of subsidiary shapes and combinations, from the plate to the sphere, that present themselves.

Rubber springs are generally cylindrical or barrel shaped; the elliptic and helical as the names imply, have respectively the shape of an ellipse and helix. The helical spring is generally made of a material cylindrical in cross section, though that is not always the case.

The different kinds of pneumatic springs that have been introduced, have consisted, mainly, of metallic cylinders with pistons.

THE SIZES of springs vary, from the delicate hair spring of the watch, in which the increase or decrease of one one hundredth part of an inch in the length makes a great change in the action of the spring, to springs that are large enough to be used to propel street cars.

Of the smallest kind of springs used, that is to say, the hair springs of time pieces, there is a variety: we have the flat spiral, which was the form up to the time of Arnold, who introduced the helical spring. The Breguet spring, the body of which is flat, with the outer coil bent upwards with a gentle sweep, and again bent so as to bring the length parallel to the plane of the spring; from there it is curved toward the center.

Houriet, a Swiss watch-maker, invented a balance spring, spherical in form.

In Sheffield they have means of making springs from fifty to sixty feet in length, capable when coiled of exerting a pressure of 800 to 900 pounds.

In France steel driving bands with great elasticity are made one hundred yards in length.

#### USES.

Springs are used to resist shock, to make dynamometrical observations, to transmit force, to store energy, to regulate motion, &c.

The rubber spring which is used to resist shock, is generally used on railways, either by itself or in connection with metallic springs, the main point in its application being to prevent abrasion, which would soon destroy the material.

With the many applications of elliptic springs to wagons, carts, carriages, &c., every one is familiar.

The helical spring serves us best for

making dynamometrical observations. All the three kinds just mentioned are extensively used to resist shock. To store energy we mostly use the coiled spring, as the main spring of the watch.

As an example of the use of a spring for regulating motion, we have the hair spring of the time piece.

An important application of springs is made in supplying the force to close incomplete pairs of elements, as in case of spring packed pistons, spring pawls for ratchet wheels, &c.

#### MANUFACTURE.

The general process of making springs is to give to the material its proper form, and then subject it to a temperature that will give it the desired elasticity:

The spring of the form of a solid block, when made of rubber, is manufactured by winding a sheet of rubber properly manipulated on an iron mandrel and then vulcanizing it.

The elliptic spring is made of a series of plates, held together by bands and worked by the ordinary processes of forging and tempering. There is generally a continuous or hoop plate upon which the reinforce or short leaves are distributed, inside at the ends and outside at the center, thus distributing the action over the whole length of the hoop.

The helical spring is made by coiling the wire or rod of which it is to be made on a mandrel, by means of a proper guide curve and then tempering.

The pneumatic spring is made by the processes of an ordinary machine shop.

#### HELICAL SPRINGS.

The spring which is usually designated "The Spiral Spring" has the form of a helix: this form is necessary where it is to be used as an accurate means for measuring force, the deflection of the helix being constant for equal loads.

In these springs the coils are closed in the normal position if it is to be subjected to tension in the direction of its axis; if it is to be used as a pressure organ, the coils are not in contact in this position.

Accuracy in the measurement of a force presupposes that the tension organ should be used; for during extension it preserves almost the true helical form and the coils remain in the cylindrical surface; but during compression, the spring, if long, is apt

to buckle, and thus lose its proper figure. In the latter case, it is kept approximately in figure by being enclosed in a cylindrical casing, or held in position by a rod passing through the axis of the helix, which should be of such dimensions as not to impede the longitudinal motion of the spring. In making tests with helical springs, the diameter of the interior of the pipe which enclosed them was one quarter inch greater than the outside diameter of the coils; thus giving one eighth play all around between the spring and the pipe.

When there is danger that the spring may be subjected to a pressure greater than its intended bearing capacity, the pressure organ is to be used in preference to the tension organ; in the first case, if the coils be pressed home the spring is not necessarily broken; in the latter case if the loads are very great the spring must uncoil itself or break.

The form of the cross section as already mentioned is generally circular; because the action of the spring depends upon the torsion of the wire, and the laws of torsion are known with greater precision for a circular form of section than for any other.

The springs used upon railways are always compressed, and it is found best to place them in such a way, that the weight will be distributed equally over the entire circumference of the extremity of the cylindrical surface formed by the helix.

This can be done by tapering the ends of the rod before coiling, in such a manner that when the spiral is completed it is terminated by a plain annular surface at each extremity, so that if placed endwise upon a flat plate its axis will be perpendicular to the plate: the same end is attained by putting a casting on each extremity of the spring, in such a manner that it will fulfill with them the same conditions as mentioned above.

The first method is represented in Fig. 1, the second in Fig. 2. The springs are made of fluted steel; their bearing or sustaining power being considered, by some authorities, greater than if the wire were round. A portion of the steel is removed on the line of the neutral axis and put in the heads of the bar giving it greater tempering surface. It consists of two or more helical

FIG. 1.

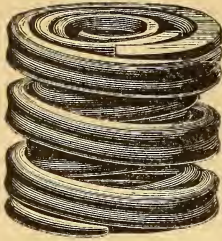
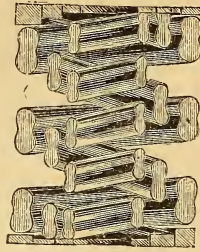


FIG. 2.



coils placed one within the other, forming a nest. The coils do not come in contact, and are consequently free from any friction whatever, while their sustaining power is materially increased. While acting in conjunction they have each a free and independent action, without abrasion; the full and proper power of each coil, being brought into requisition, producing easy, elastic and uniform action without wearing the spring. When the metallic surfaces of a spring come into contact, so as to produce friction, the usefulness of the spring is impaired in a corresponding degree.

FIG. 3.

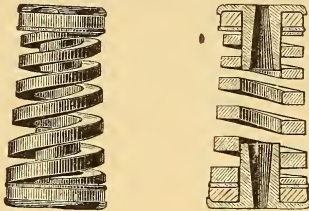


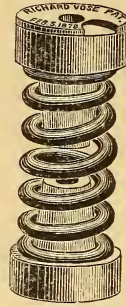
Fig. 3 represents a spring composed of a bar of steel that tapers in width or thickness or both from end to end, with a packing of India rubber at each end, supporting the light load on the apex; as the load increases the lighter coils close, bringing into requisition the heavier coils or base of the spring. This spring fills a want long felt for one that can be used for light or heavy loads as on railway cars.

We have also the helical cluster spring, consisting of a group of (6) six or (7) seven springs in a case of round or oblong form, as may be desired, in Fig. 5.

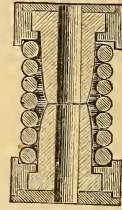
The *helical spring* is made by coiling a steel wire or rod of the required size, on a cylindrical mandrel, to the requisite pitch and length, tempering and testing

it. The *modus operandi* is essentially the same—from the heavy car spring, weighing over sixty pounds to the delicate hair spring of the watch.

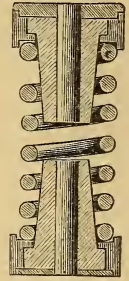
FIGS. 4.



Elevation.



Exhausted.

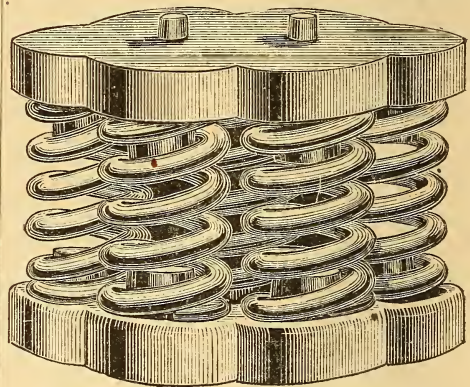


Section.

Figs. 4 represent the Vose Graduated Spring for City Railway Cars. It is so constructed that the spiral alone carries the empty car, and as the load increases, the elastic cones are brought into requisition, the whole gradually accumulating power without friction or abrasion, imparting a soft, easy motion. It has been thoroughly tested, and answers its requirements in every particular.

The steel is generally heated to redness before coiling, but sometimes is coiled cold. The essential difference between the machines for coiling consists in the guide gauge for the wire.

FIG. 5.



The operation is as follows: the heated rod is taken from the oven or furnace, pinched upon the mandrel by means of a dog, and when the machine begins operations a jaw, driven by a screw feed, seizes the rod and guides it so as to produce a helix of the required

pitch and length; sometimes the jaw is dispensed with and the steel made to take its proper form by sliding directly on the worm. A machine now in use in a Newark spring factory consists of an iron frame about four feet high carrying a shaft with a pulley, by means of which power is applied. This shaft, by interposition of gears, turns the mandrel on which the spring is wound, and also the guide curves. These guide curves are in front of the coiling mandrel, the axes of the two being parallel. By means of a lever, the mandrel may be drawn out of its position in a direction along its axis, in which movement the coil strikes a tappet projecting from above, and the spring is thus stripped from the mandrel. The spring is held upon the mandrel by a small dog, shaped like a hook, which grasps the steel.

#### TEMPERING.

When steel is heated to a high temperature and suddenly cooled it is hardened; when the temperature is gradually lowered it is softened; between these two extremes any degree of hardness may be obtained.

Spring steel being generally hard when it leaves the manufacturer, the spring maker's first care is to heat it to facilitate him in his work of coiling and shaping it; this process necessarily softens the material and renders a re-hardening requisite to give it the proper temper. The majority of manufacturers temper their springs in oil baths. The oil is kept at the proper temperature by cold water circulating through pipes that run through and around the reservoir; or it may be kept cool by being forced through a perforated plate and, falling into a chamber, meeting a current of cool air coming from an opposite direction. Economy in oil may thus be practiced and with equally satisfactory results. The springs are cleaned by placing them in a revolving cylinder, partly filled with sawdust; or by being introduced into a solution of potash.

The ovens for heating the springs before coiling and tempering are usually three in number, and are made of fire-brick: the coke used is directly under the lowest of the three, and the heat passes, in its upward course, under and

around the other two, thus producing three separate and distinct temperatures, which enable us to obtain with certainty three grades of hardness.

The ovens are so constructed as to heat the steel without burning, keeping all the good qualities and not subjecting it to chemical deterioration. These ovens have their retorts vertically above each other, and the furnace, which is under the lowest one, has its fire-door on the front side with the doors of the retorts.

Another form of oven may be constructed as follows: there are four brick walls with a roof and chimney, the section is a square, the sides of which are twelve feet in length, and the walls are eight feet in height. The wall which forms the front has an iron plate bolted to it in which there are three apertures provided with iron doors; these iron doors open to the retorts in which the steel is heated. The retorts are twelve feet long and semi-circular in section, the diameter of the section is about two feet, the wall opposite has a door opening to the furnace within, the oven being thus fired from behind. The grate is fifteen inches in width and feet long; the flame and heated gas pass from the grate around one of the retorts, and in their return around the other two (the center one being a little above the level of the other two), and then pass into the chimney; the retorts are lined with fire-brick; the chimney whose outside cross section is about two feet square, is four feet high, and is provided with a smoke pipe, one foot in diameter and fifteen feet high; the oven and chimney are provided with buck staves, which are held by one inch bolts: the oven is provided with hand holes for cleaning.

In the manufacture of springs, the retorts are sometimes dispensed with, and the springs are placed directly on the coke; nor are they always re-heated after working and before tempering, but are placed directly in the oil after leaving the mandrel. It is admitted, however, that the use of the retorts and the re-heating before tempering are the preferable methods, the results being much surer.

In some shops a second tempering is given in lead baths; this seems to be a kind of annealing and is rarely used; the

spring is plunged into molten lead and kept there till its temperature equals that of the lead; then cooled gradually in the open air.

The *Scientific Record* says that springs are generally hardened by being immersed in various compositions of oil, suet, wax and like materials, and, after being taken from the composition, held over a clear coke fire till the grease inflames: this is called "blazing off."

A greatly recommended composition consists of two lbs. of suet, and a quarter lb. of bees wax to every gallon of whale oil. These are boiled together and will serve for thin articles and most kinds of steel; the addition of black resin, to the extent of about one pound to the gallon, makes it sure for thicker pieces, and for those it refused to harden on the first trial; the composition becomes useless after it has been constantly employed for about a month; the period, however, depends upon the extent to which it has been used; the trays should be thoroughly cleansed before a new mixture is placed in them. The following is also recommended:

- 20 gallons spermaceti oil.
- 20 lbs. melted and strained beef suet.
- 1 gallon neats-foot oil.
- 1 lb. pitch.
- 3 lbs. black resin.

The last two articles must be previously melted together and then added to the other ingredients; the whole must then be heated in a proper iron vessel fitted with a close cover, until the moisture is entirely evaporated, and the composition will take fire upon a flaming body being presented to its surface. For a *spring temper* the whole of the fatty composition must burn away from its surface, if the work is thick; or if unequally thick and thin, as in some springs, a second and third dose is burned off to insure equality of temperature at all points alike.

Gun lock springs are sometimes literally fried in oil for a considerable time over a fire in an iron tray; the thick parts are then sure to be sufficiently reduced, and the thin parts do not become the more softened from the continuance of the blazing heat.

Springs do not appear to lose their elasticity, after the hardening and tem-

pering, from the reduction they are compelled to undergo in grinding and polishing.

#### TESTING MACHINES.

There are a variety of testing machines. Hydraulic presses are at times used. The principal part of the hydraulic press is a ram, which carries the table on which the spring to be used is placed. On top of the machine is a lever to be weighted with any desirable load at the other end. The load rests on a support, until the pressure of the ram under the spring is great enough to lift the lever and its weight at the extremity. Thus the lever and the weight gauge the pressure to which the spring is subjected. Steam power is used for working the pump which raises the ram.

Another form of machine consists of a table worked by a screw from below. The springs are loaded by means of a lever.

A third one which is extensively used consists of a platform sliding vertically; this platform is supported by a stout iron rod and is worked from below by means of a connecting rod and crank, a lever measures the pressure on the spring.

These three machines give the behavior of the springs when subjected to pressure only a few times. In practice a spring is subjected to pressure till it is worthless; hence the above tests give no idea of the endurance of a spring.

In Europe spring testers for the latter information consist of slotting machines under which the springs are placed; the stroke of the head is made equal to the action of the spring; thus by every stroke the spring is compressed. A counter attached to the machine gives the number of strokes, and consequently the endurance.

The following is the method to be pursued when springs are made in a machine shop. It is the substance of an article on the manufacture of helical springs by Mr. Rose, in the *Scientific American*, *Supt. No. 20*, May 13, 1876.

The means employed are a lathe and a mandrel with a groove. In the regular coiling machines the mandrels are plane and the wire is guided by separate guide curves.

The mandrel for forming a brass spring has a helical groove of the proper pitch,

of less diameter than the spring, and a little longer to make room for the lathe dog.

On one end is placed a washer rather larger than the outside diameter of the spring when secured upon the mandrel, and provided with a keyway and key; slipping the washer over, the mandrel is placed in the lathe between the centers and the loose washer slid back against its dead center; the end of the spring wire is passed through the hole in the mandrel and pulled close, bending it over the corner of the hole, and tapped lightly with a hammer. Holding the wire firmly against the mandrel, the lathe is started and the spring wound, taking care that it winds closely. When wound to the requisite length the washer is slipped up and the key driven home and the wire cut. Placing the mandrel, with the spring, on an iron block, the spring is hammered, setting the wire to the mandrel and hardening the brass. It is important to hammer and set the wire to its form; otherwise it would uncoil to a spring of larger diameter and less length; the mandrel should not be hammered while on the centers, they might be injured and the mandrel bent.

If the wire is too stiff to be held against the mandrel by hand, the gearing (if the lathe is a self-acting one) necessary to cut a thread, of the same pitch as that of the required spring, is put on and a grooved piece of metal is fastened into the tool post, which acts as a guide. If the lathe is not self-acting and has a hand slide rest, the screw feed is taken from the straight feed of the rest and the metal guide used, allowing the groove to carry the wire along; the groove being in this case three-eighths as deep as the diameter of the wire; and if of iron or brass it is taken to the anvil and hammered all over its circumference equally and evenly, with blows at not more than one-fourth inch apart, otherwise there cannot be maintained any definite relation between the size of the mandrel and that of the spring; but if of steel, the mandrel and the spring must be heated together to a low, red heat, to set the spring to the mandrel, as the hammering in this case would only close the grain and add to its elasticity without having much effect in making it hug the mandrel, except in case of very small wire.

#### HARDENING.

Springs of light wire, or those long in proportion to their diameter, should be placed on a mandrel fitting loosely and heated while on it to prevent bending and disarrangement of the coils during the heating process. The fire should be clear, of green coal; some times a fire is built around a piece of gas pipe, with the spring inserted; this causes the spring to be uniformly heated. Being heated to a cherry red, the spring must be plunged into clear water slightly heated, and held there till quite cold.

If it is then found black and not evenly mottled with white spots it would indicate an insufficient hardness arising from the quality of the steel or insufficient heating; steel when of good quality is sufficiently heated when it just forms scales on coming from the fire.

If the hardening process is found difficult, the water should be salted till it becomes a strong brine and the hardening repeated till the steel appears white when taken out of the water, as it will if well hardened; the whiteness of the surface being a better test than the file would be, because steel of a straw color will not file, and any degree of hardness, between straw color and white cannot be distinguished by this test.

The temper of a spring, lowered from a white hardness to a blue, is not the same as that lowered from a black or even a mottled hardness to a blue, and hence for the sake of evenness in the temper, all those of a dark or mottled appearance should be reheated.

#### TEMPERING.

The most reliable method of tempering an ordinary spring, is to "blaze it off:" *i. e.* fry or boil it off in the oil, heating and reheating the oil to a blaze, and dipping and redipping it in two or three times; after the boiling and the blazing takes place freely all over the spring, and has, on the last removal from the tank, burned out at any one point it should be placed in warm water and left to cool.

The thicker the spring the longer it should be subjected to this process of blazing and dipping, so that every part of the spring shall be equally heated inside and out. It is well

that the spring should be reversed and revolved in the oil, that it should not accumulate at any one point and thus make an uneven temper. A good oil composition consists of

Spermaceti oil . . . one gallon.  
Neats foot oil . . . . . one gallon.  
Rendered beef suet. one pound.  
Resin . . . . . quarter pound.

The tank should have a close fitting cover which will put out the blaze when the tempering is finished.

THE HELICAL BALANCE SPRING of a watch is made from drawn steel wire, giving the material the necessary form and fastening it so as to be capable of further manipulation; the spring is subjected to a heat sufficient to turn the wire blue, when it will retain its shape, or it may be subjected directly to the fire which makes it more durable. The mode of operation is simple, and is as follows: the wire is wound upon a hollow cylinder which is smooth or grooved, the thickness not being more than one-eighth of its diameter, otherwise it would cool too slowly. The cylinder with the spring is placed in an iron box which has a loose cover, the inner space being about three times the diameter of the spring and somewhat deeper; the box is filled with powdered charcoal mixed with powdered ivory, and the whole heated to a yellow heat in which it is kept one minute. It is then reversed over a vessel of oil, the loose top and cylinder falling into it. It will be evenly heated throughout and never change its form, a contingency which sometimes happens when water is used. At times platina foil is wrapped around the spring to exclude the air, it can then be heated on a piece of charcoal by means of a blowpipe; for hardening cold water is used in this case.

#### APPLICATION OF RUBBER.

In building railway cars the effect of two kinds of movements have to be considered.

1st. Jolts and shocks: a shock is produced by the impinging of one mass against another, whereby the velocity of one or both of the masses is suddenly changed, or in common parlance, it is a blow produced by one solid body striking another.

Railway springs resist shocks, as bear-

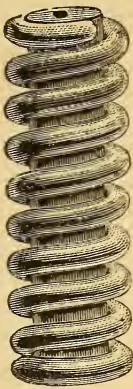
ing springs which diminish shock between rail and wheel, as buffer springs intended to reduce the effect of shock in the direction of the train's length, and as traction springs, intended to reduce the shock in traveling and prevent the breaking of connections. The springs used should be sensitive; that is to say of rapid action. They should yield through a sufficient space in proportion to the jolt; for if a moving mass be brought to rest by a resistance acting through a certain space, the longer the space the less the shock.

2d. What are known as jars or tremors which are produced by forces moving with great rapidity through very small spaces. The jolts or shocks can be met by a spring made of steel, but the jars are so much more rapidly propagated than the time which the spring requires to move, that they are transmitted through the steel spring exactly as if it were a rigid body. Rubber, by yielding instantaneously to the pressure, takes up the jar; consequently when both movements are to be encountered, a combination of rubber and steel is necessary. Rubber has been used with helical springs for another reason. When a helical spring is subjected to a pressure it increases its resistance, when its limit of loading is approached; but the resistance does not, at times, increase rapidly enough to prevent a shock which happens when the spring is subjected to so great a load as to close the coils. This shock often breaks the spring. The difficulty is overcome by placing a core of rubber within the helix; now, when the spring is compressed, the rubber is compressed also and necessarily bulges out laterally, thus forming a cushion between the coils. The resistance of the cushion\* increases rapidly with the shortening of the spring, and produces an almost insensible transition from the free yielding, to the absolute cessation of motion which occurs when the coils touch each other.\* The combination would do very well were it not for the fact that the rubber under this condition is soon destroyed.

The bulging out of the rubber is necessary for the preservation of the elasticity of the core, but it must not be accom-

\* G. W. Robertson, Class of 1876.

FIG. 6.



panied by abrasion. Rubber confined is, so to say, not elastic; the experiment has been tried of placing a rubber cylinder of the same density as that

used for car springs in an aperture made in a stout piece of steel, and subjecting it longitudinally to pressure. It was found to have very little elasticity. Fig. 6 represents a rubber center helical spring; the hole through the center allows it to expand and contract without abrasion; its action is uniform and it is not affected by moisture. The following shows the elasticity of Vose, Dinsmore & Co.'s rubber center helical springs of a length equal to  $5\frac{1}{2}$  inches and diameter of  $2\frac{1}{8}$  inches, and the number required for carrying various loads, the diameter of the wire being  $\frac{1}{16}$  inches.

The first horizontal line of figures in the table gives the deflection in inches produced by any load, given in the vertical column beneath the recorded deflection, for the number of springs given in the first vertical column.

## LOAD IN GROSS TONS.

10-Coil Rubber Center Spiral Springs.				Maximum Working Load.								Weight of Springs per load to be Carried.
Elasticity in Ins.	0.27	0.45	0.67		0.83	0.98	1.09	1.16	1.22	1.28	1.33	
2 Springs with rubber centers	0.223	0.446	0.669	0.893	1.116	1.339	1.562	1.785	2.008	2.232	3.75	
4    "    "	0.446	0.892	1.338	1.786	2.232	2.678	3.124	3.575	4.016	4.464	7.50	
6    "    "	0.669	1.338	2.007	2.679	3.348	4.017	4.680	5.355	6.024	6.696	11.25	
8    "    "	0.892	1.784	2.676	3.572	4.464	5.356	6.248	7.140	8.032	8.928	15.00	
10   "    "	1.115	2.230	3.345	4.465	5.580	6.695	7.810	8.925	10.040	11.160	18.75	
12   "    "	1.338	2.676	4.014	5.358	6.696	8.034	9.372	10.710	12.048	13.392	22.50	
14   "    "	1.561	3.122	4.683	6.251	7.812	9.373	10.934	12.495	14.056	15.624	26.25	
16   "    "	1.784	3.568	5.352	7.114	8.928	10.712	12.496	14.280	16.064	17.856	30.00	
18   "    "	2.007	4.014	6.021	8.037	10.044	12.051	14.058	16.065	18.072	20.078	33.75	
20   "    "	2.230	4.46	6.69	8.93	11.16	13.39	15.62	17.85	20.080	22.320	37.50	
22   "    "	2.453	4.90	7.66	9.82	12.27	14.72	17.18	19.63	22.088	24.552	41.25	
24   "    "	2.676	5.35	8.02	10.71	13.39	16.06	18.74	21.42	24.096	26.784	45.00	
26   "    "	2.899	5.80	8.69	11.61	14.50	17.40	20.30	23.20	26.104	29.016	48.75	
28   "    "	3.122	6.24	9.36	12.50	15.62	18.74	21.86	25.00	28.112	31.248	52.50	
30   "    "	3.345	6.69	10.03	13.39	16.74	20.03	23.43	26.77	30.120	33.480	56.25	
32   "    "	3.568	7.13	10.70	14.28	17.85	21.42	25.00	28.66	32.128	35.712	60.00	
34   "    "	3.791	7.58	11.37	15.18	18.97	22.76	26.56	30.34	34.136	37.944	63.75	
36   "    "	4.014	8.02	12.04	16.07	20.08	24.10	28.12	32.13	36.144	40.176	67.50	
38   "    "	4.237	8.47	12.71	16.87	21.20	25.44	29.67	33.91	38.152	42.408	71.25	
40   "    "	4.460	8.92	13.38	17.86	22.32	26.78	31.24	35.70	40.160	44.640	75.00	
44   "    "	4.906	9.81	14.71	19.64	24.55	29.45	34.36	39.27	44.176	49.104	82.50	
48   "    "	5.352	10.70	16.05	21.43	26.78	32.13	37.48	42.84	48.192	53.568	90.00	

The above calculations are based upon Tests made by Mr. David Kirkaldy, at his Testing Works, Southwark, England.

## DURATION OF STEEL AND IRON RAILS.

From "Iron."

THE following figures refer to the main line of the Cologne-Minden railway, which has a total length of way of 1357 miles, or double that length of rails in use, exclusive of colliery sidings. At the end of 1876 more than 90 per cent. of the whole was laid with steel, the substitution for iron having been in progress since 1864. The effect of this on the maintenance of the line is seen in the following table:

Renewals in 1870, 7.75 per cent. of total length.		
" 1871, 8.77	"	"
" 1872, 7.55	"	"
" 1873, 8.40	"	"
" 1874, 4.33	"	"
" 1875, 1.04	"	"
" 1876, 1.13	"	"

The rate at which the actual substitution of steel for iron proceeded is given in the following table, representing the number of Bessemer steel rails laid down and removed in each year since 1868:

Year.	No. of rails in use at end of year.	No. of rails laid during year.	Removed as useless during year.	Percentage of length in use.	Rails broken before laying.
1868	1,853				
1869	21,867	20,014	31	0.142	No. 3
1870	78,259	56,392	20	0.025	" 4
1871	139,618	61,359	54	0.039	" 18
1872	222,844	83,226	93	0.042	" 41
1873	340,300	117,456	342	0.101	" 173
1874	452,650	112,350	738	0.158	" 8
1875	504,634	51,984	347	0.069	" 2
1876	514,801	10,167	310	0.060	" 2
			1,935	0.376	251 = 0.049 per cent.

Out of the total of 1935 rails rendered unserviceable, 1204 broke through the full section, 227 through the fish-bolt holes, and 504 were otherwise damaged. That the number of removals does not increase, but has substantially diminished since 1874, is accounted for by the fact that these removals are necessitated not so much by wear as by defects in manufacture, which are usually discovered within a short time after the rail has been laid.

In order to obtain accurate data as to the comparative efficiency of different classes of rails, a number of samples from different makers were laid on a part of the line having the heaviest traffic, near the Oberhausen station. The experiment commenced in 1864, and the results obtained up to the end of 1876 were as follows. The rails were all of the same section, called Calibre IV., and 5650 millimeters area:

Description of rail.	Laid in 1864	Remaining in 1876.	Average wear of head.	Removals in twelve years.	
Fine-grained iron from Friedrich-Wilhelm Hutte, Troisdorf.....	No. 150	No. 29	Mil. ..	No. 121	Per cent. 80.66
Case-hardened iron from Phenix-Hutte	150	48	4.44	102	68.00
Puddle steel, Funke & Co., Hagen....	12	8	4.72	4	33.33
Puddle steel, E. Hosch & Sons, Lendersdorf.....	12	8	4.72	4	33.33
Bessemer steel, E. Hosch & Sons.....	149	142	5.22	7	4.70
Bessemer steel, F. Krupp.....	147	141	5.18	6	4.08
Bessemer steel, Horder Verein.....	150	148	4.18	2	1.33

The average wear of the experimental Bessemer rails is 4.86, which represents the effect produced by the passage of 6,500,000 axles of passenger and goods trains, or about 1,340,000 axles for each millimeter of wear.

## MATTER AND MOTION.

BY J. CLERK MAXWELL, LL.D., F.R.S.

## II.

## CHAPTER V.

## ON WORK AND ENERGY.

**DEFINITIONS.**—*Work is the act of producing a change of configuration in a system in opposition to a force which resists that change.*

*Energy is the capacity of doing work.*

*When the nature of a material system is such that if, after the system has undergone any series of changes, it is brought back in any manner to its original state, the whole work done by external agents on the system is equal to the whole work done by the system in overcoming external forces, the system is called a CONSERVATIVE SYSTEM.*

**PRINCIPLE OF CONSERVATION OF ENERGY.**—The progress of physical science has led to the discovery and investigation of different forms of energy, and to the establishment of the doctrine that all material systems may be regarded as conservative systems, provided that all the different forms of energy which exist in these systems are taken into account.

This doctrine, considered as a deduction from observation and experiment can, of course, assert no more than that no instance of a non-conservative system has hitherto been discovered.

As a scientific or science-producing doctrine, however, it is always acquiring additional credibility from the constantly increasing number of deductions which have been drawn from it, and which are found in all cases to be verified by experiment.

In fact the doctrine of the Conservation of Energy is the one generalized statement which is found to be consistent with fact, not in one physical science only, but in all.

When once apprehended it furnishes to the physical inquirer a principle on which he may hang every known law relating to physical actions, and by which he may be put in the way to discover the relations of such actions in new branches of science.

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For such reasons the doctrine is commonly called the Principle of the Conservation of Energy.

**GENERAL STATEMENT OF THE PRINCIPLE OF THE CONSERVATION OF ENERGY.**—*The total energy of any material system is a quantity which can neither be increased nor diminished by any action between the parts of the system, though it may be transformed into any of the forms of which energy is susceptible.*

If, by the action of some agent external to the system, the configuration of the system is changed, while the forces of the system resist this change of configuration, the external agent is said to do work on the system. In this case the energy of the system is increased by the amount of work done on it by the external agent.

If, on the contrary, the forces of the system produce a change of configuration which is resisted by the external agent, the system is said to do work on the external agent, and the energy of the system is diminished by the amount of work which it does.

Work, therefore, is a transference of energy from one system to another; the system which gives out energy is said to do work on the system which receives it, and the amount of energy given out by the first system is always exactly equal to that received by the second.

If, therefore, we include both systems in one larger system, the energy of the total system is neither increased nor diminished by the action of the one partial system on the other.

**MEASUREMENT OF WORK.**—Work done by an external agent on a material system may be described as a change in the configuration of the system taking place under the action of an external force tending to produce that change.

Thus, if one pound is lifted one foot from the ground by a man in opposition to the force of gravity, a certain amount of work is done by the man, and this quantity is known among engineers as one foot-pound.

Here the man is the external agent, the material system consists of the earth and the pound, the change of configuration is the increase of the distance between the matter of the earth and the matter of the pound, and the force is the upward force exerted by the man in lifting the pound, which is equal and opposite to the weight of the pound. To raise the pound a foot higher would, if gravity were a uniform force, require exactly the same amount of work. It is true that gravity is not really uniform, but diminishes as we ascend from the earth's surface, so that a foot-pound is not an accurately known quantity, unless we specify the intensity of gravity at the place. But for the purpose of illustration we may assume that gravity is uniform for a few feet of ascent, and in that case the work done in lifting a pound would be one foot-pound for every foot the pound is lifted.

To raise twenty pounds of water ten feet high requires 200 foot-pounds of work. To raise one pound ten feet high requires ten foot-pounds, and as there are twenty pounds the whole work is twenty times as much, or two hundred foot-pounds.

The quantity of work done is, therefore, proportional to the product of the numbers representing the force exerted and the displacement in the direction of the force.

In the case of a foot-pound the force is the weight of a pound—a quantity which, as we know, is different in different places. The weight of a pound expressed in absolute measure is numerically equal to the intensity of gravity, the quantity denoted by  $g$ , the value of which in poundals to the pound varies from 32.227 at the pole to 32.117 at the equator, and diminishes without limit as we recede from the earth. In dynes to the gramme it varies from 978.1 to 983.1. Hence, in order to express work in a uniform and consistent manner, we must multiply the number of foot-pounds by the number representing the intensity of gravity at the place. The work is thus reduced to foot-poundals. We shall always understand work to be measured in this manner and reckoned in foot-poundals when no other system of measurement is mentioned. When work is expressed in foot-pounds the system is that

of *gravitation-measures*, which is not a complete system unless we also know the intensity of gravity at the place.

In the metrical system the unit of work is the Erg, which is the work done by a dyne acting through a centimeter. There are 421393.8 ergs in a foot-poundal.

**POTENTIAL ENERGY.**—The work done by a man in raising a heavy body is done in overcoming the attraction between the earth and that body. The energy of the material system, consisting of the earth and the heavy body, is thereby increased. If the heavy body is the leaden weight of a clock, the energy of the clock is increased by winding it up, so that the clock is able to go for a week in spite of the friction of the wheels and the resistance of the air to the motion of the pendulum, and also to give out energy in other forms, such as the communication of the vibrations to the air, by which we hear the ticking of the clock.

When a man winds up a watch he does work in changing the form of the mainspring by coiling it up. The energy of the mainspring is thereby increased, so that as it uncoils itself it is able to keep the watch going.

In both these cases the energy communicated to the system depends upon a change of configuration.

**KINETIC ENERGY.**—But in a very important class of phenomena the work is done in changing the velocity of the body on which it acts. Let us take as a simple case that of a body moving without rotation under the action of a force. Let the mass of the body be  $M$  pounds, and let a force of  $F$  poundals act on it in the line of motion during an interval of time,  $T$  seconds. Let the velocity at the beginning of the interval be  $V$  and that at the end  $V'$  feet per second, and let the distance traveled by the body during the time be  $S$  feet. The original momentum is  $MV$ , and the final momentum is  $MV'$ , so that the increase of momentum is  $M(V' - V)$ , and this, by the second law of motion is equal to  $FT$ , the *impulse* of the force  $F$  acting for the time  $T$ . Hence

$$FT = M(V' - V). \quad (1)$$

Since the velocity increases uniformly

with the time, the mean velocity is the arithmetical mean of the original and final velocities, or  $\frac{1}{2}(V' + V)$ .

We can also determine the mean velocity by dividing the space  $S$  by the time  $T$ , during which it is described.

$$\text{Hence } \frac{S}{T} = \frac{1}{2}(V' + V). \quad (2)$$

Multiplying the corresponding members of equations (1) and (2) each by each we obtain—

$$FS = \frac{1}{2} MV'^2 - \frac{1}{2} MV^2 \quad (3)$$

Here  $FS$  is the work done by the force  $F$  acting on the body while it moves through the space  $S$  in the direction of the force, and this is equal to the excess of  $\frac{1}{2} MV'^2$  above  $\frac{1}{2} MV^2$ . If we call  $\frac{1}{2} MV^2$ , or half the product of the mass, into the square of the velocity, the *kinetic energy* of the body at first, then  $\frac{1}{2} MV'^2$  will be the kinetic energy after the action of the force  $F$  through the space  $S$ . The energy is here expressed in foot-pounds.

We may now express the equation in words by saying that the work done by the force  $F$  in changing the motion of the body is measured by the increase of the kinetic energy of the body during the time that the force acts.

We have proved that this is true when the interval of time is so small that we may consider the force as constant during that time, and the mean velocity during the interval as the arithmetical mean of the velocities at the beginning and end of the interval. This assumption, which is exactly true when the force is constant, however long the interval may be, becomes in every case more and more nearly true as the interval of time taken becomes smaller and smaller. By dividing the whole time of action into small parts, and proving that in each of these the work done is equal to the increase of the kinetic energy of the body, we may, by adding the successive portions of the work and the successive increments of energy, arrive at the result that the total work done by the force is equal to the total increase of kinetic energy.

If the force acts on the body in the direction opposite to its motion, the kinetic energy of the body will be diminished instead of being increased, and the force,

instead of doing work on the body, will act as a resistance, which the body, in its motion, overcomes. Hence a moving body, as long as it is in motion, can do work in overcoming resistance, and the work done by the moving body is equal to the diminution of its kinetic energy, till at last, when the body is brought to rest, its kinetic energy is exhausted, and the whole work it has done is then equal to the whole kinetic energy which it had at first.

We now see the appropriateness of the name *kinetic energy*, which we have hitherto used merely as a name to denote the product  $\frac{1}{2} MV^2$ . For the energy of a body has been defined as the capacity which it has of doing work, and it is measured by the work which it can do. The *kinetic energy* of a body is the energy it has in virtue of being in *motion*, and we have now shown that its value is expressed by  $\frac{1}{2} MV^2$  or  $\frac{1}{2} MV \times V$ , that is, half the product of its momentum into its velocity.

**OBLIQUE FORCES.**—If the force acts on the body at right angles to the direction of its motion it does not work on the body, and it alters the direction but not the magnitude of the velocity. The kinetic energy, therefore, which depends on the square of the velocity, remains unchanged.

If the direction of the force is neither coincident with, nor at right angles to, that of the motion of the body we may resolve the force into two components, one of which is at right angles to the direction of motion, while the other is in the direction of motion (or in the opposite direction).

The first of these components may be left out of consideration in all calculations about energy, since it neither does work on the body nor alters its kinetic energy.

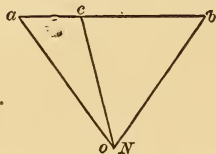
The second component is that which we have already considered. When it is in the direction of motion it increases the kinetic energy of the body by the amount of work which it does on the body. When it is in the opposite direction the kinetic energy of the body is diminished by the amount of work which the body does against the force.

Hence in all cases the increase of kinetic energy is equal to the work done on

the body by external agency, and the diminution of kinetic energy is equal to the work done by the body against external resistance.

**KINETIC ENERGY OF TWO PARTICLES REFERRED TO THEIR CENTER OF MASS.**—The kinetic energy of a material system is equal to the kinetic energy of a mass equal to that of the system moving with the velocity of the center of mass of the system, together with the kinetic energy due to the motion of the parts of the system relative to its center of mass.

FIG. 10.



Let us begin with the case of two particles whose masses are A and B, and whose velocities are represented in the diagram of velocities by the lines  $oa$  and  $ob$ . If  $c$  is the center of mass of a particle equal to A placed at  $a$ , and a particle equal to B placed at  $b$ , then  $oc$  will represent the velocity of the center of mass of the two particles.

The kinetic energy of the system is the sum of the kinetic energies of the particles, or

$$T = \frac{1}{2} A \overline{oa}^2 + \frac{1}{2} B \overline{ob}^2.$$

Expressing  $\overline{oa}^2$  and  $\overline{ob}^2$  in terms of  $oc$ ,  $ca$  and  $cb$  and the angle  $oca = \theta$ .

$$T = \frac{1}{2} A \overline{oc}^2 + \frac{1}{2} A \overline{ca}^2 - A \cdot oc \cdot ca \cos \theta + \frac{1}{2} B \overline{oc}^2 + \frac{1}{2} B \overline{cb}^2 - B \cdot oc \cdot cb \cos \theta.$$

But since  $c$  is the center of mass of A at  $a$ , and B at  $b$ ,

$$A \cdot \overline{ca} + B \cdot \overline{cb} = 0.$$

Hence adding

$$T = \frac{1}{2} (A+B) \overline{oc}^2 + \frac{1}{2} A \overline{ca}^2 + \frac{1}{2} B \overline{cb}^2,$$

or, the kinetic energy of the system of two particles A and B is equal to that of a mass equal to  $(A+B)$  moving with the velocity of the center of mass, together with that of the motion of the particles relative to the center of mass.

**KINETIC ENERGY OF A MATERIAL SYS-**

**TEM REFERRED TO ITS CENTER OF MASS.**—We have begun with the case of two particles, because the motion of a particle is assumed to be that of its center of mass, and we have proved our proposition true for a system of two particles. But if the proposition is true for each of two material systems taken separately, it must be true of the system which they form together. For if we now suppose  $oa$  and  $ob$  to represent the velocities of the centers of mass of two material systems A and B, then  $oc$  will represent the velocity of the center of mass of the combined system  $A+B$ , and if  $T_A$  represents the kinetic energy of the motion of the system A relative to its own center of mass, and  $T_B$  the same for the system B, then if the proposition is true for the systems A and B taken separately, the kinetic energy of A is

$$\frac{1}{2} A \overline{oa}^2 + T_A,$$

and that of B

$$\frac{1}{2} B \overline{ob}^2 + T_B.$$

The kinetic energy of the whole is, therefore,

$$\frac{1}{2} A \overline{oa}^2 + \frac{1}{2} B \overline{ob}^2 + T_A + T_B,$$

or,

$$\frac{1}{2} (A+B) \overline{oc}^2 + \frac{1}{2} A \overline{ca}^2 + T_A + \frac{1}{2} B \overline{cb}^2 + T_B.$$

The first term represents the kinetic energy of a mass equal to that of the whole system moving with the velocity of the center of mass of the whole system.

The second and third terms, taken together, represent the kinetic energy of the system A relative to the center of gravity of the whole system, and the fourth and fifth terms represent the same for the system B.

Hence if the proposition is true for the two systems A and B taken separately, it is true for the system compounded of A and B. But we have proved it true for the case of two particles; it is, therefore, true for three, four, or any other number of particles, and therefore for any material system.

The kinetic energy of a system referred to its center of mass is less than its kinetic energy when referred to any other point.

For the latter quantity exceeds the former by a quantity equal to the

kinetic energy of a mass equal to that of the whole system moving with the velocity of the center of mass relative to the other point, and since all kinetic energy is essentially positive, this excess must be positive.

**AVAILABLE KINETIC ENERGY.**—We have already seen in "The Motion of the Center of Mass," etc., that the mutual action between the parts of a material system cannot change the velocity of the center of mass of the system. Hence that part of the kinetic energy of the system which depends on the motion of the center of mass cannot be affected by any action internal to the system. It is therefore, impossible, by means of the mutual action of the parts of the system, to convert this part of the energy into work. As far as the system itself is concerned, this energy is unavailable. It can be converted into work only by means of the action between this system and some other material system external to it.

Hence if we consider a material system unconnected with any other system, its available kinetic energy is that which is due to the motions of the parts of the system relative to its center of mass.

Let us suppose that the action between the parts of the system is such that after a certain time the configuration of the system becomes invariable, and let us call this process the solidification of the system. We have shown that the angular momentum of the whole system is not changed by any mutual action of its parts. Hence if the original angular momentum is zero, the system, when its form becomes invariable, will not rotate about its center of mass, but if it moves at all will move parallel to itself, and the parts will be at rest relative to the center of mass. In this case, therefore, the whole available energy will be converted into work by the mutual action of the parts during the solidification of the system.

If the system has angular momentum, it will have the same angular momentum when solidified. It will therefore rotate about its center of mass, and will therefore still have energy of motion relative to its center of mass, and this remaining kinetic energy has not been converted into work.

But if the parts of the system are allowed to separate from one another in directions perpendicular to the axis of the angular momentum of the system, and if the system when thus expanded is solidified, the remaining kinetic energy of rotation round the center of mass will be less and less the greater the expansion of the system, so that by sufficiently expanding the system we may make the remaining kinetic energy as small as we please, so that the whole kinetic energy relative to the center of mass of the system may be converted into work within the system.

**POTENTIAL ENERGY.**—The potential energy of a material system is the capacity which it has of doing work depending on other circumstances than the motion of the system. In other words, potential energy is that energy which is not kinetic.

In the theoretical material system which we build up in our imagination from the fundamental ideas of matter and motion, there are no other conditions present except the configuration and motion of the different masses of which the system is composed. Hence in such a system the circumstances upon which the energy must depend are motion and configuration only, so that, as the kinetic energy depends on the motion, the potential energy must depend on the configuration.

In many real material systems we know that part of the energy does depend on the configuration. Thus the mainspring of a watch has more energy when coiled up than when partially uncoiled, and two bar magnets have more energy when placed side by side with their similar poles turned the same way than when their dissimilar poles are placed next each other.

**ELASTICITY.**—In the case of the spring we may trace the connection between the coiling of the spring and the force which it exerts somewhat further by conceiving the spring divided (in imagination) into very small parts or elements. When the spring is coiled up, the form of each of these small parts is altered, and such an alteration of the form of a solid body is called a Strain.

In solid bodies strain is accompanied

with internal force or stress; those bodies in which the stress depends simply on the strain are called Elastic, and the property of exerting stress when strained is called Elasticity.

We thus find that the coiling of the spring involves the strain of its elements, and that the external force which the spring exerts is the resultant of the stresses in its elements.

We thus substitute for the immediate relation between the coiling of the spring and the force which it exerts a relation between the strains and stresses of the elements of the spring; that is to say, for a single displacement and a single force, the relation between which may in some cases be of an exceedingly complicated nature, we substitute a multitude of strains and an equal number of stresses, each strain being connected with its corresponding stress by a much more simple relation.

But when all is done, the nature of the connection between configuration and force remains as mysterious as ever. We can only admit the fact, and if we call all such phenomena phenomena of elasticity, we may find it very convenient to classify them in this way, provided we remember that by the use of the word elasticity we do not profess to explain the cause of the connection between configuration and energy.

**ACTION AT A DISTANCE.**—In the case of the two magnets there is no visible substance connecting the bodies between which the stress exists. The space between the magnets may be filled with air or with water, or we may place the magnets in a vessel and remove the air by an air-pump, till the magnets are left in what is commonly called a vacuum, and yet the mutual action of the magnets will not be altered. We may even place a solid plate of glass or metal or wood between the magnets, and still we find that their mutual action depends simply on their relative position, and is not perceptibly modified by placing any substance between them, unless that substance is one of the magnetic metals. Hence the action between the magnets is commonly spoken of as *action at a distance*.

Attempts have been made, with a cer-

tain amount of success,\* to analyze this action at a distance into a continuous distribution of stress in an invisible medium, and thus to establish an analogy between the magnetic action and the action of a spring or a rope in transmitting force; but still the general fact that strains or changes of configuration are accompanied by stresses or internal forces, and that thereby energy is stored up in the system so strained, remains an ultimate fact which has not yet been explained as the result of any more fundamental principle.

**THEORY OF POTENTIAL ENERGY MORE COMPLICATED THAN THAT OF KINETIC ENERGY.**—Admitting that the energy of a material system may depend on its configuration, the mode in which it so depends may be much more complicated than the mode in which the kinetic energy depends on the motion of the system. For the kinetic energy may be calculated from the motion of the parts of the system by an invariable method. We multiply the mass of each part by half the square of its velocity, and take the sum of all such products. But the potential energy arising from the mutual action of two parts of the system may depend on the relative position of the parts in a manner which may be different in different instances. Thus when two billiard balls approach each other from a distance, there is no sensible action between them till they come so near one another that certain parts appear to be in contact. To bring the centers of the two balls nearer, the parts in contact must be made to yield, and this requires the expenditure of work.

Hence in this case the potential energy is constant for all distances greater than the distance of first contact, and then rapidly increases when the distance is diminished.

The force between magnets varies with the distance in a very different manner, and in fact we find that it is only by experiment that we can ascertain the form of the relation between the configuration of a system and its potential energy.

**APPLICATION OF THE METHOD OF ENERGY TO THE CALCULATION OF FORCES.**

\* See Clerk Maxwell's "Treatise on Electricity and Magnetism," Vol. II., Art. 641.

—A complete knowledge of the mode in which the energy of a material system varies when the configuration and motion of the system are made to vary is mathematically equivalent to a knowledge of all the dynamical properties of the system. The mathematical methods by which all the forces and stresses in a moving system are deduced from the single mathematical formula which expresses the energy as a function of the variables have been developed by Lagrange, Hamilton, and other eminent mathematicians, but it would be difficult even to describe them in terms of the elementary ideas to which we restrict ourselves in this book. An outline of these methods is given in my treatise on Electricity, Part IV., Chapter V., Article 553, and the application of these dynamical methods to electro-magnetic phenomena is given in the chapters immediately following.

But if we consider only the case of a system at rest it is easy to see how we can ascertain the forces of the system when we know how its energy depends on its configuration.

For let us suppose that an agent external to the system produces a displacement from one configuration to another, then if in the new configuration the system possess more energy than it did at first, it can have received this increase of energy only from the external agent. This agent must therefore have done an amount of work equal to the increase of energy. It must therefore have exerted force in the direction of the displacement, and the mean value of this force, multiplied into the displacement, must be equal to the work done. Hence the mean value of the force may be found by dividing the increase of energy by the displacement.

If the displacement is large this force may vary considerably during the displacement, so that it may be difficult to calculate its mean value; but since the force depends on the configuration, if we make the displacement smaller and smaller the variation of the force will become smaller and smaller, so that at last the force may be regarded as sensibly constant during the displacement.

If, therefore, we calculate for a given configuration the *rate* at which the energy increases with the displacement, by a

method similar to that described "On the Measurement of Velocity when Variable;" "Diagram of Velocities," and "On the Rate of Acceleration," this rate will be numerically equal to the force exerted by the external agent in the direction of the displacement.

If the energy diminishes instead of increasing as the displacement increases, the system must do work on the external agent, and the force exerted by the external agent must be in the direction opposite to that of displacement.

**SPECIFICATION OF THE DIRECTION OF FORCES.**—In treatises on dynamics the forces spoken of are usually those exerted by the external agent on the material system. In treatises on electricity, on the other hand, the forces spoken of are usually those exerted by the electrified system against an external agent which prevents the system from moving. It is necessary, therefore, in reading any statement about forces, to ascertain whether the force spoken of is to be regarded from the one point of view or the other.

We may in general avoid any ambiguity by viewing the phenomenon as a whole, and speaking of it as a stress exerted between two points or bodies, and distinguishing it as a tension or a pressure, an attraction or a repulsion, according to its direction, "Action and Reaction are the Partial Aspects of a Stress."

**APPLICATION TO A SYSTEM IN MOTION.**—It thus appears that from a knowledge of the potential energy of a system in every possible configuration we may deduce all the external forces which are required to keep the system in that configuration. If the system is at rest, and if these external forces are the actual forces, the system will remain in equilibrium. If the system is in motion the force acting on each particle is that arising from the connections of the system (equal and opposite to the external force just calculated), together with any external force which may be applied to it. Hence a complete knowledge of the mode in which the potential energy varies with the configuration would enable us to predict every possible motion of the system under the action of given external forces, provided we were able

to overcome the purely mathematical difficulties of the calculation.

**APPLICATION OF THE METHOD OF ENERGY TO THE INVESTIGATION OF REAL BODIES.**—When we pass from abstract dynamics to physics—from material systems, whose only properties are those expressed by their definitions, to real bodies, whose properties we have to investigate—we find that there are many phenomena which we are not able to explain as changes in the configuration and motion of a material system.

Of course if we begin by assuming that the real bodies are systems composed of matter which agrees in all respects with the definitions we have laid down, we may go on to assert that all phenomena are changes of configuration and motion, though we are not prepared to define the kind of configuration and motion by which the particular phenomena are to be explained. But in accurate science such asserted explanations must be estimated, not by their promises, but by their performances. The configuration and motion of a system are facts capable of being described in an accurate manner, and therefore, in order that the explanation of a phenomenon by the configuration and motion of a material system may be admitted as an addition to our scientific knowledge, the configurations, motions, and forces must be specified, and shown to be consistent with known facts, as well as capable of accounting for the phenomenon.

**VARIABLES ON WHICH THE ENERGY DEPENDS.**—But even when the phenomena we are studying have not yet been explained dynamically, we are still able to make great use of the principle of the conservation of energy as a guide to our researches.

To apply this principle, we in the first place assume that the quantity of energy in a material system depends on the state of that system, so that for a given state there is a definite amount of energy.

Hence the first step is to define the different states of the system, and when we have to deal with real bodies we must define their state with respect not only to the configuration and motion of their visible parts, but if we have reason to suspect that the configuration and

motion of their invisible particles influence the visible phenomenon, we must devise some method of estimating the energy thence arising.

Thus pressure, temperature, electric potential, and chemical composition are variable quantities, the values of which serve to specify the state of a body, and in general the energy of the body depends on the values of these and other variables.

#### ENERGY IN TERMS OF THE VARIABLES.

—The next step in our investigation is to determine how much work must be done by external agency on the body in order to make it pass from one specified state to another.

For this purpose it is sufficient to know the work required to make the body pass from a particular state, which we may call the *standard state*, into any other specified state. The energy in the latter state is equal to that in the standard state, together with the work required to bring it from the standard state into the specified state. The fact that this work is the same through whatever series of states the system has passed from the standard state to the specified state is the foundation of the whole theory of energy.

Since all the phenomena depend on the variations of the energy of the body, and not on its total value, it is unnecessary, even if it were possible, to form any estimate of the energy of the body in its standard state.

**THEORY OF HEAT.**—One of the most important applications of the principle of the conservation of energy is to the investigation of the nature of heat.

At one time it was supposed that the difference between the states of a body when hot and when cold was due to the presence of a substance called caloric, which existed in greater abundance in the body when hot than when cold. But the experiments of Rumford on the heat produced by the friction of metal, and of Davy on the melting of ice by friction, have shown that when work is spent in overcoming friction, the amount of heat produced is proportional to the work spent.

The experiments of Hirn have also shown that when heat is made to do work

in a steam-engine, part of the heat disappears, and that the heat which disappears is proportional to the work done.

A very careful measurement of the work spent in friction, and of the heat produced, has been made by Joule, who finds that the heat required to raise one pound of water from 39° F. to 40° F. is equivalent to 772 foot-pounds of work at Manchester, or 24,858 foot-pounds.

From this we may find that the heat required to raise one gramme of water from 3° C. to 4° C. is 42,000,000 ergs.

**HEAT A FORM OF ENERGY.**—Now, since heat can be produced it cannot be a substance; and since whenever mechanical energy is lost by friction there is a production of heat, and whenever there is a gain of mechanical energy in an engine there is a loss of heat; and since the quantity of energy lost or gained is proportional to the quantity of heat gained or lost, we conclude that heat is a form of energy.

We have also reasons for believing that the minute particles of a hot body are in a state of rapid agitation, that is to say, that each particle is always moving very swiftly, but that the direction of its motion alters so often that it makes little or no progress from one region to another.

If this be the case, a part, and it may be a very large part, of the energy of a hot body must be in the form of kinetic energy.

But for our present purpose it is unnecessary to ascertain in what form energy exists in a hot body; the most important fact is that energy may be measured in the form of heat, and since every kind of energy may be converted into heat, this gives us one of the most convenient methods of measuring it.

**ENERGY MEASURED AS HEAT.**—Thus when certain substances are placed in contact chemical actions take place, the substances combine in a new way, and the new group of substances has different chemical properties from the original group of substances. During this process mechanical work may be done by the expansion of the mixture, as when gunpowder is fired; an electric current may be produced, as in the voltaic battery; and heat may be generated, as in most chemical actions.

The energy given out in the form of mechanical work may be measured directly, or it may be transformed into heat by friction. The energy spent in producing the electric current may be estimated as heat by causing the current to flow through a conductor of such a form that the heat generated in it can easily be measured. Care must be taken that no energy is transmitted to a distance in the form of sound or radiant heat without being duly accounted for.

The energy remaining in the mixture, together with the energy which has escaped, must be equal to the original energy.

Andrews, Favre and Silbermann, and others, have measured the quantity of heat produced when a certain quantity of oxygen or of chlorine combines with its equivalent of other substances. These measurements enable us to calculate the excess of the energy which the substances concerned had in their original state, when uncombined, above that which they have after combination.

**SCIENTIFIC WORK TO BE DONE.**—Though a great deal of excellent work of this kind has already been done, the extent of the field hitherto investigated appears quite insignificant when we consider the boundless variety and complexity of the natural bodies with which we have to deal.

In fact the special work which lies before the physical inquirer, in the present state of science, is the determination of the quantity of energy which enters or leaves a material system during the passage of the system from its standard state to any other definite state.

**HISTORY OF THE DOCTRINE OF ENERGY.**—The scientific importance of giving a name to the quantity which we call kinetic energy seems to have been first recognized by Leibnitz, who gave to the product of the mass by the square of the velocity the name of *Vis Viva*. This is twice the kinetic energy.

Newton, in the "Scholium to the Laws of Motion," expresses the relation between the rate at which work is done by the external agent, and the rate at which it is given out, stored up, or transformed by any machine or other material system, in the following state-

ment, which he makes in order to show the wide extent of the application of the Third Law of Motion.

"If the action of the external agent is estimated by the product of its force into its velocity, and the reaction of the resistance in the same way by the product of the velocity of each part of the system into the resisting force arising from friction, cohesion, weight, and acceleration, the action and reaction will be equal to each other, whatever be the nature and motion of the system." That this statement of Newton's implicitly contains nearly the whole doctrine of energy was first pointed out by Thomson and Tait.

The words Action and Reaction as they occur in the enunciation of the Third Law of Motion are explained to mean Forces, that is to say, they are the opposite aspects of one and the same Stress.

In the passage quoted above a new and different sense is given to these words by estimating Action and Reaction by the product of a force into the velocity of its point of application. According to this definition the Action of the external agent is the rate at which it does work. This is what is meant by the Power of a steam-engine or other prime mover. It is generally expressed by the estimated number of ideal horses which would be required to do the work at the same rate as the engine, and this is called the Horse-power of the engine.

When we wish to express by a single word the rate at which work is done by an agent we shall call it the Power of the agent, defining the power as the work done in the unit of time.

The use of the term Energy, in a precise and scientific sense, to express the quantity of work which a material system can do, was introduced by Dr. Young.\*

#### ON THE DIFFERENT FORMS OF ENERGY.

—The energy which a body has in virtue of its motion is called kinetic energy.

A system may also have energy in virtue of its configuration, if the forces of the system are such that the system will do work against external resistance while it passes into another configuration.

This energy is called Potential Energy. Thus when a stone has been lifted to a certain height above the earth's surface, the system of two bodies, the stone and the earth, has potential energy, and is able to do a certain amount of work during the descent of the stone. This potential energy is due to the fact that the stone and the earth attract each other, so that work has to be spent by the man who lifts the stone and draws it away from the earth, and after the stone is lifted the attraction between the earth and the stone is capable of doing work as the stone descends. This kind of energy, therefore, depends upon the work which the forces of the system would do if the parts of the system were to yield to the action of these forces. This is called the "Sum of the Tensions" by Helmholtz in his celebrated memoir on the "Conservation of Energy."\* Thomson called it Statical Energy; it has also been called Energy of Position; but Rankine introduced the term Potential Energy—a very felicitous expression, since it not only signifies the energy which the system has not in actual possession, but only has the power to acquire, but it also indicates its connection with what has been called (on other grounds) the Potential Function.

The different forms in which energy has been found to exist in material systems have been placed in one or other of these two classes—Kinetic Energy, due to motion, and Potential Energy, due to configuration.

Thus a hot body, by giving out heat to a colder body, may be made to do work by causing the cold body to expand in opposition to pressure. A material system, therefore, in which there is a non-uniform distribution of temperature has the capacity of doing work, or energy. This energy is now believed to be kinetic energy, due to a motion of agitation in the smallest parts of the hot body.

Gunpowder has energy, for when fired it is capable of setting a cannon-ball in motion. The energy of gunpowder is Chemical Energy, arising from the power which the constituents of gunpowder possess of arranging themselves in a new manner when exploded, so as

\* "Lectures on Natural Philosophy," Lecture VIII.

\* Berlin, 1847. Translated in Taylor's "Scientific Memoirs," Feb. 1853.

to occupy a much larger volume than the gunpowder does. In the present state of science chemists figure to themselves chemical action as a rearrangement of particles under the action of forces tending to produce this change of arrangement. From this point of view, therefore, chemical energy is potential energy.

Air, compressed in the chamber of an air-gun, is capable of propelling a bullet. The energy of compressed air was at one time supposed to arise from the mutual repulsion of its particles. If this explanation were the true one its energy would be potential energy. In more recent times it has been thought that the particles of the air are in a state of motion, and that its pressure is caused by the impact of these particles on the sides of the vessel. According to this theory the energy of compressed air is kinetic energy.

There are thus many different modes in which a material system may possess energy, and it may be doubtful in some cases whether the energy is of the kinetic or the potential form. The nature of energy, however, is the same in whatever form it may be found. The quantity of energy can always be expressed as that of a body of a definite mass moving with a definite velocity.

## CHAPTER VI.

### RECAPITULATION.

#### RETROSPECT OF ABSTRACT DYNAMICS.

—We have now gone through the part of the fundamental science of the motion of matter, which we have been able to treat in a manner sufficiently elementary to be consistent with the plan of this book.

It remains for us to take a general view of the relations between the parts of this science, and of the whole to other physical sciences, and this we can now do in a more satisfactory way than we could before we had entered into the subject.

**KINEMATICS.**—We began with kinematics, or the science of pure motion. In this division of the subject the ideas brought before us are those of space and time. The only attribute of matter which comes before us is its continuity

of existence in space and time—the fact, namely, that every particle of matter, at any instant of time, is in one place and in one only, and that its change of place during any interval of time is accomplished by moving along a continuous path.

Neither the force which affects the motion of the body, nor the mass of the body, on which the amount of force required to produce the motion depends, comes under our notice in the pure science of motion.

**FORCE.**—In the next division of the subject force is considered in the aspect of that which alters the motion of a mass.

If we confine our attention to a single body, our investigation enables us, from observation of its motion, to determine the direction and magnitude of the resultant force which acts on it, and this investigation is the exemplar and type of all researches undertaken for the purpose of the discovery and measurement of physical forces.

But this may be regarded as a mere application of the definition of a force, and not as a new physical truth.

It is when we come to define equal forces as those which produce equal rates of acceleration in the same mass, and equal masses are those which are equally accelerated by equal forces, that we find that these definitions of equality amount to the assertion of the physical truth, that the comparison of quantities of matter by the forces required to produce in them a given acceleration is a method which always leads to consistent results, whatever be the absolute values of the forces and the accelerations.

**STRESS.**—The next step in the science of force is that in which we pass from the consideration of a force as acting on a body, to that of its being one aspect of that mutual action between two bodies, which is called by Newton Action and Reaction, and which is now more briefly expressed by the single word Stress.

**RELATIVITY OF DYNAMICAL KNOWLEDGE.**—Our whole progress up to this point may be described as a gradual development of the doctrine of relativity

of all physical phenomena. Position we must evidently acknowledge to be relative, for we cannot describe the position of a body in any terms which do not express relation. The ordinary language about motion and rest does not so completely exclude the notion of their being measured absolutely, but the reason of this is, that in our ordinary language we tacitly assume that the earth is at rest.

As our ideas of space and motion become clearer, we come to see how the whole body of dynamical doctrine hangs together in one consistent system.

Our primitive notion may have been that to know absolutely where we are, and in what direction we are going, are essential elements of our knowledge as conscious beings.

But this notion, though undoubtedly held by many wise men in ancient times, has been gradually dispelled from the minds of students of physics.

There are no landmarks in space; one portion of space is exactly like every other portion, so that we cannot tell where we are. We are, as it were, on an unruffled sea, without stars, compass, soundings, wind, or tide, and we cannot tell in what direction we are going. We have no log which we can cast out to take a dead reckoning by; we may compute our rate of motion with respect to the neighboring bodies, but we do not know how these bodies may be moving in space.

**RELATIVITY OF FORCE.**—We cannot even tell what force may be acting on us; we can only tell the difference between the force acting on one thing and that acting on another.

We have an actual example of this in our every-day experience. The earth moves round the sun in a year at a distance of 91,520,000 miles, or  $1.473 \times 10^{13}$  centimeters. It follows from this that a force is exerted on the earth in the direction of the sun, which produces an acceleration of the earth in the direction of the sun of about 0.019 in feet and seconds, or about  $\frac{1}{1680}$  of the intensity of gravity at the earth's surface.

A force equal to the sixteen-hundredth part of the weight of a body might be easily measured by known experimental methods, especially if the direction of this force were differently inclined to

the vertical at different hours of the day.

Now, if the attraction of the sun were exerted upon the solid part of the earth, as distinguished from the movable bodies on which we experiment, a body suspended by a string, and moving with the earth, would indicate the difference between the solar action on the body, and that on the earth as a whole.

If, for example, the sun attracted the earth and not the suspended body, then at sunrise the point of suspension, which is rigidly connected with the earth, would be drawn towards the sun, while the suspended body would be acted on only by the earth's attraction, and the string would appear to be deflected away from the sun by a sixteen-hundredth part of the length of the string. At sunset the string would be deflected away from the setting sun by an equal amount; and as the sun sets at a different point of the compass from that at which he rises the deflections of the string would be in different directions, and the difference in the position of the plumb-line at sunrise and sunset would be easily observed.

But instead of this, the attraction of gravitation is exerted upon all kinds of matter equally at the same distance from the attracting body. At sunrise and sunset the center of the earth and the suspended body are nearly at the same distance from the sun, and no deflection of the plumb-line due to the sun's attraction can be observed at these times. The attraction of the sun, therefore, in so far as it is exerted equally upon all bodies on the earth, produces no effect on their relative motions. It is only the differences of the intensity and direction of the attraction acting on different parts of the earth which can produce any effect, and these differences are so small for bodies at moderate distances that it is only when the body acted on is very large, as in the case of the ocean, that their effect becomes perceptible in the form of tides.

**ROTATION.**—In what we have hitherto said about the motion of bodies, we have tacitly assumed that, in comparing one configuration of the system with another, we are able to draw a line in the final configuration parallel to a line in

the original configuration. In other words, we assume that there are certain directions in space which may be regarded as constant, and to which other directions may be referred during the motion of the system.

In astronomy, a line drawn from the earth to a star may be considered as fixed in direction, because the relative motion of the earth and the star is in general so small compared with the distance between them that the change of direction, even in a century, is very small. But it is manifest that all such directions of reference must be indicated by the configuration of a material system existing in space, and that if this system were altogether removed, the original directions of reference could never be recovered.

But, though it is impossible to determine the absolute velocity of a body in space, it is possible to determine whether the direction of a line in a material system is constant or variable.

For instance, it is possible by observations made on the earth alone, without reference to the heavenly bodies, to determine whether the earth is rotating or not.

So far as regards the geometrical configuration of the earth and the heavenly bodies, it is evidently all the same

"Whether the sun, predominant in heaven,  
Rise on the earth, or earth rise on the sun;  
He from the east his flaming road begin,  
Or she from west her silent course advance  
With inoffensive pace that spinning sleeps  
On her soft axle, while she paces even,  
And bears thee soft with the smooth air along."

The distances between the bodies composing the universe, whether celestial or terrestrial, and the angles between the lines joining them, are all that can be ascertained without an appeal to dynamical principles, and these will not be affected if any motion of rotation of the whole system, similar to that of a rigid body about an axis, is combined with the actual motion; so that from a geometrical point of view the Copernican system, according to which the earth rotates, has no advantage, except that of simplicity, over that in which the earth is supposed to be at rest, and the apparent motions of the heavenly bodies to be their absolute motions.

Even if we go a step further, and consider the dynamical theory of the earth rotating round its axis, we may

account for its oblate figure, and for the equilibrium of the ocean and of all other bodies on its surface on either of two hypotheses—that of the motion of the earth round its axis, or that of the earth not rotating, but caused to assume its oblate figure by a force acting outwards in all directions from its axis, the intensity of this force increasing as the distance from the axis increases. Such a force, if it acted on all kinds of matter alike, would account not only for the oblateness of the earth's figure, but for the conditions of equilibrium of all bodies at rest with respect to the earth.

It is only when we go further still, and consider the phenomena of bodies which are in motion with respect to the earth, that we are really constrained to admit that the earth rotates.

#### NEWTON'S DETERMINATION OF THE ABSOLUTE VELOCITY OF ROTATION.—

Newton was the first to point out that the absolute motion of rotation of the earth might be demonstrated by experiments on the rotation of a material system. For instance, if a bucket of water is suspended from a beam by a string, and the string twisted so as to keep the bucket spinning round a vertical axis, the water will soon spin round at the same rate as the bucket, so that the system of the water and the bucket turns round its axis like a solid body.

The water in the spinning bucket rises up at the sides and is depressed in the middle, showing that in order to make it move in a circle a pressure must be exerted towards the axis. This concavity of the surface depends on the absolute motion of rotation of the water and not on its relative rotation.

For instance, it does not depend on the rotation relative to the bucket. For at the beginning of the experiment, when we set the bucket spinning, and before the water has taken up the motion, the water and the bucket are in relative motion, but the surface of the water is flat, because the water is not rotating, but only the bucket.

When the water and the bucket rotate together, there is no motion of the one relative to the other, but the surface of the water is hollow, because it is rotating.

When the bucket is stopped, as long

as the water continues to rotate its surface remains hollow, showing that it is still rotating though the bucket is not.

It is manifestly the same, as regards this experiment, whether the rotation be in the direction of the hands of a watch or the opposite direction, provided the rate of rotation is the same.

Now let us suppose this experiment tried at the North Pole. Let the bucket be made, by a proper arrangement of clockwork, to rotate either in the direction of the hands of a watch, or in the opposite direction, at a perfectly regular rate.

If it is made to turn round by clockwork once in twenty-four hours (sidereal time) the way of the hands of a watch laid face upwards, it will be rotating as regards the earth, but not rotating as regards the stars.

If the clockwork is stopped, it will rotate with respect to the stars, but not with respect to the earth.

Finally, if it is made to turn round once in twenty-four hours (sidereal time) in the opposite direction, it will be rotating with respect to the earth at the same rate as at first, but instead of being free from rotation as respects the stars, it will be rotating at the rate of one turn in twelve hours.

Hence if the earth is at rest, and the stars moving round it, the form of the surface will be the same in the first and last case; but if the earth is rotating, the water will be rotating in the last case but not in the first, and this will be made manifest by the water rising higher at the sides in the last case than in the first.

The surface of the water will not be really concave in any of the cases supposed, for the effect of gravity acting towards the center of the earth is to make the surface convex, as the surface of the sea is, and the rate of rotation in our experiment is not sufficiently rapid to make the surface concave. It will only make it slightly less convex than the surface of the sea in the last case, and slightly more convex in the first.

But the difference in the form of the surface of the water would be so exceedingly small, that with our methods of measurement it would be hopeless to attempt to determine the rotation of the earth in this way.

**FOUCAULT'S PENDULUM.**—The most satisfactory method of making an experiment for this purpose is that devised by M. Foucault.

A heavy ball is hung from a fixed point by a wire, so that it is capable of swinging like a pendulum in any vertical plane passing through the fixed point.

In starting the pendulum care must be taken that the wire, when at the lowest point of the swing, passes exactly through the position it assumes when hanging vertically. If it passes on one side of this position, it will return on the other side, and this motion of the pendulum round the vertical instead of through the vertical must be carefully avoided, because we wish to get rid of all motions of rotation either in one direction or the other.

Let us consider the angular momentum of the pendulum about the vertical line through the fixed point.

At the instant at which the wire of the pendulum passes through the vertical line, the angular momentum about the vertical line is zero.

The force of gravity always acts parallel to this vertical line, so that it cannot produce angular momentum round it. The tension of the wire always acts through the fixed point, so that it cannot produce angular momentum about the vertical line.

Hence the pendulum can never acquire angular momentum about the vertical line through the point of suspension.

Hence when the wire is out of the vertical, the vertical plane through the center of the ball and the point of suspension cannot be rotating; for if it were, the pendulum would have an angular momentum about the vertical line.

Now let us suppose this experiment performed at the North Pole. The plane of vibration of the pendulum will remain absolutely constant in direction, so that if the earth rotates the rotation of the earth will be made manifest.

We have only to draw a line on the earth parallel to the plane of vibration, and to compare the position of this line with that of the plane of vibration at a subsequent time.

As a pendulum of this kind properly suspended will swing for several hours, it is easy to ascertain whether the posi-

sition of the plane of vibration is constant as regards the earth, as it would be if the earth is at rest, or constant as regards the stars, if the stars do not move round the earth.

We have supposed, for the sake of simplicity in the description, that the experiment is made at the North Pole. It is not necessary to go there in order to demonstrate the rotation of the earth.

The only region where the experiment will not show it is at the equator.

At every other place the pendulum will indicate the rate of rotation of the earth with respect to the vertical line at that place. If at any instant the plane of the pendulum passes through a star near the horizon either rising or setting, it will continue to pass through that star as long as it is near the horizon. That is to say, the horizontal part of the apparent motion of a star on the horizon is equal to the rate of rotation of the plane of vibration of the pendulum.

It has been observed that the plane of vibration appears to rotate in the opposite direction in the southern hemisphere, and by a comparison of the rates at various places the actual time of rotation of the earth has been deduced without reference to astronomical observations. The mean value, as deduced from these experiments by Messrs. Galbraith and Houghton in their "Manual of Astronomy," is  $23^{\text{h}}. 53^{\text{m}}. 37^{\text{s}}$ . The true time of rotation of the earth is  $23^{\text{h}}. 56^{\text{m}}. 4^{\text{s}}$ . mean solar time.

**MATTER AND ENERGY.**—All that we know about matter relates to the series of phenomena in which energy is transferred from one portion of matter to another, till in some part of the series our bodies are affected, and we become conscious of a sensation.

By the mental process which is founded on such sensations we come to learn the conditions of these sensations, and to trace them to objects which are not part of ourselves, but in every case the fact that we learn is the mutual action between bodies. This mutual action we have endeavored to describe in this treatise. Under various aspects it is called Force, Action and Reaction, and Stress, and the evidence of it is the change of the motion of the bodies between which it acts.

The process by which stress produces change of motion is called Work, and, as we have already shown, work may be considered as the transference of Energy from one body or system to another.

Hence, as we have said, we are acquainted with matter only as that which may have energy communicated to it from other matter, and which may, in its turn, communicate energy to other matter.

Energy, on the other hand, we know only as that which in all natural phenomena is continually passing from one portion of matter to another.

**TEST OF A MATERIAL SUBSTANCE.**—Energy cannot exist except in connection with matter. Hence since, in the space between the sun and the earth, the luminous and thermal radiations, which have left the sun and which have not reached the earth, possess energy, the amount of which per cubic mile can be measured; this energy must belong to matter existing in the interplanetary spaces, and since it is only by the light which reaches us that we become aware of the existence of the most remote stars, we conclude that the matter which transmits light is disseminated through the whole of the visible universe.

**ENERGY NOT CAPABLE OF IDENTIFICATION.**—We cannot identify a particular portion of energy, or trace it through its transformations. It has no individual existence, such as that which we attribute to particular portions of matter.

The transactions of the material universe appear to be conducted, as it were, on a system of credit. Each transaction consists of the transfer of so much credit or energy from one body to another. This act of transfer or payment is called work. The energy so transferred does not retain any character by which it can be identified when it passes from one form to another.

**ABSOLUTE VALUE OF THE ENERGY OF A BODY UNKNOWN.**—The energy of a material system can only be estimated in a relative manner.

In the first place, though the energy of the motion of the parts relative to the center of mass of the system may be accurately defined, the whole energy con-



order to keep it in the circle of radius  $v$ , in which it is moving with velocity  $V$ .

The direction of this force is towards the center of the circle.

If this force is applied by means of a string fastened to the body, the string will be in a state of tension. To a person holding the other end of the string this tension will appear to be directed towards the body  $M$ , as if the body  $M$  had a tendency to move away from the center of the circle which it is describing.

Hence this latter force is often called Centrifugal Force.

The force which really acts on the body, being directed towards the center of the circle, is called Centripetal Force, and in some popular treatises the centripetal and centrifugal forces are described as opposing and balancing each other. But they are merely the different aspects of the same stress.

**PERIODIC TIME.**—The time of describing the circumference of the circle is called the Periodic Time. If  $\pi$  represents the ratio of the circumference of a circle to its diameter, which is 3.14159 . . . . . the circumference of a circle of radius  $r$  is  $2\pi r$ , and since this is described in the periodic time  $T$  with velocity  $V$ , we have

$$2\pi r = VT$$

Hence 
$$F = 4\pi^2 M \frac{r}{T^2}$$

The rate of circular motion is often expressed by the number of revolutions in unit of time. Let this number be denoted by  $n$ , then

$$nT = 1 \\ \text{and } F = 4\pi^2 M r n^2.$$

**ON SIMPLE HARMONIC VIBRATIONS.**—If while the body  $M$  (Fig. 11) moves in a circle with uniform velocity another point  $P$  moves in a fixed diameter of the circle, so as to be always at the foot of the perpendicular from  $M$  on that diameter, the body  $P$  is said to execute Simple Harmonic Vibrations.

The radius,  $r$ , of the circle is called the Amplitude of the vibration.

The periodic time of  $M$  is called the Periodic Time of Vibration.

The angle which  $OM$  makes with the

positive direction of the fixed diameter is called the Phase of the vibration.

**ON THE FORCE ACTING ON THE VIBRATING BODY.**—The only difference between the motions of  $M$  and  $P$  is that  $M$  has a vertical motion compounded with a horizontal motion which is the same as that of  $P$ . Hence the velocity and the acceleration of the two bodies differ only with respect to the vertical part of the velocity and acceleration of  $M$ .

The acceleration of  $P$  is therefore the horizontal component of that of  $M$ , and since the acceleration of  $M$  is represented by  $OA$ , which is in the direction of  $MO$  produced, the acceleration of  $P$  will be represented by  $OB$ , where  $B$  is the foot of the perpendicular from  $A$  on the horizontal diameter. Now by similar triangles  $OMP$ ,  $OAB$

$$OM : OA :: OP : OB$$

But  $OM = r$  and  $OA = -4\pi^2 \frac{r}{T^2}$ . Hence

$$OB = -\frac{4\pi^2}{T^2} OP = -4\pi^2 n^2 OP$$

In simple harmonic vibration, therefore, the acceleration is always directed towards the center of vibration, and is equal to the distance from that center multiplied by  $4\pi^2 n^2$ , and if the mass of the vibrating body is  $P$ , the force acting on it at a distance  $x$  from  $O$  is  $4\pi^2 n^2 P x$ .

It appears, therefore, that a body which executes simple harmonic vibrations in a straight line is acted on by a force which varies as the distance from the center of vibration, and the value of this force at a given distance depends only on that distance, on the mass of the body, and on the square of the number of vibrations in unit of time, and is independent of the amplitude of the vibrations.

**ISOCRONOUS VIBRATIONS.**—It follows from this that if a body moves in a straight line and is acted on by a force directed towards a fixed point on the line and varying as the distance from that point, it will execute simple harmonic vibrations, the periodic time of which will be the same whatever the amplitude of vibration.

If, for a particular kind of displace-

ment of a body, as turning round an axis, the force tending to bring it back to a given position varies as the displacement, the body will execute simple harmonic vibrations about that position, the periodic time of which will be independent of their amplitude.

Vibrations of this kind, which are executed in the same time whatever be their amplitude, are called Isochronous Vibrations.

**POTENTIAL ENERGY OF THE VIBRATING BODY.**—The velocity of the body when it passes through the point of equilibrium is equal to that of the body moving in the circle, or  $V = 2\pi r n$ , where  $r$  is the amplitude of vibration and  $n$  is the number of double vibrations per second.

Hence the kinetic energy of the vibrating body at the point of equilibrium is

$$\frac{1}{2} M V^2 = 2\pi^2 M r^2 n^2$$

where  $M$  is the mass of the body.

At the extreme elongation, where  $x=r$ , the velocity, and therefore the kinetic energy, of the body is zero. The diminution of kinetic energy must correspond to an equal increase of potential energy. Hence if we reckon the potential energy from the configuration in which the body is at its point of equilibrium, its potential energy when at a distance,  $r$ , from this point is  $2\pi^2 M n^2 r^2$ .

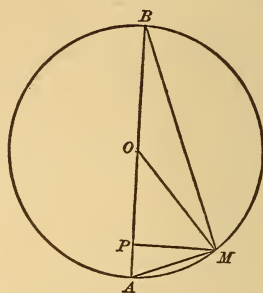
This is the potential energy of a body which vibrates isochronously, and executes  $n$  double variations per second when it is at rest at the distance,  $r$ , from the point of equilibrium. As the potential energy does not depend on the motion of the body, but only on its position, we may write it  $2\pi^2 M n^2 x^2$ ,

where  $x$  is the distance from the point of equilibrium.

**THE SIMPLE PENDULUM.**—The simple pendulum consists of a small heavy body called the bob, suspended from a fixed point by a fine string of invariable length. The bob is supposed to be so small that its motion may be treated as that of a material particle, and the string is supposed to be so fine that we may neglect its mass and weight. The bob is set in motion so as to swing through a small angle in a vertical plane. Its

path, therefore, is an arc of a circle, whose center is the point of suspension,  $O$ , and whose radius is the length of the string, which we shall denote by  $l$ .

FIG. 12.



Let  $O$  (Fig. 12) be the point of suspension and  $O A$  the position of the pendulum when hanging vertically. When the bob is at  $M$  it is higher than when it is at  $A$  by the height  $AP = \frac{AM^2}{AB}$

where  $AM$  is the chord of the arc  $AM$  and  $AB = 2l$ .

If  $M$  be the mass of the bob and  $g$  the intensity of gravity the weight of the bob will be  $Mg$  and the work done against gravity during the motion of the bob from  $A$  to  $M$  will be  $Mg \overline{AP}$ . This, therefore, is the potential energy of the pendulum when the bob is at  $M$ , reckoning the energy zero when the bob is at  $A$ .

We may write this energy

$$\frac{Mg}{2l} \overline{AM}^2$$

The potential energy of the bob when displaced through any arc varies as the square of the chord of that arc.

If it had varied as the square of the arc itself in which the bob moves, the vibrations would have been strictly isochronous. As the potential energy varies more slowly than the square of the arc, the period of each vibration will be greater when the amplitude is greater.

For very small vibrations, however, we may neglect the difference between the chord and the arc, and denoting the arc by  $x$  we may write the potential energy

$$\frac{Mg}{2l} x^2$$

But we have already shown that in har-

monic vibrations the potential energy is  $2\pi^2 Mn^2 x^2$ .

Equating these two expressions and clearing fractions we find

$$g = 4\pi^2 n^2 l,$$

where  $g$  is the intensity of gravity,  $\pi$  is the ratio of the circumference of a circle to its diameter,  $n$  is the number of vibrations of the pendulum in unit of time, and  $l$  is the length of the pendulum.

**A RIGID PENDULUM.**—If we could construct a pendulum with a bob so small and a string so fine that it might be regarded for practical purposes as a simple pendulum, it would be easy to determine  $g$  by this method. But all real pendulums have bobs of considerable size, and in order to preserve the length invariable the bob must be connected with the point of suspension by a stout rod, the mass of which cannot be neglected. It is always possible, however, to determine the length of a simple pendulum whose vibrations would be executed in the same manner as those of a pendulum of any shape.

The complete discussion of this subject would lead us into calculations beyond the limits of this treatise. We may, however, arrive at the most important result without calculation as follows:

The motion of a rigid body in one plane may be completely defined by stating the motion of its center of mass, and the motion of the body round its center of mass.

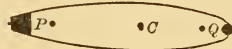
The force required to produce a given change in the motion of the center of mass depends only on the mass of the body. "Effect of External Forces on the Motion of the Center of Mass."

The moment required to produce a given change of angular velocity about the center of mass depends on the distribution of the mass, being greater the further the different parts of the body are from the center of mass.

If, therefore, we form a system of two particles rigidly connected, the sum of the masses being equal to the mass of a pendulum, their center of mass coinciding with that of the pendulum, and their distances from the center of mass being such that a couple of the same moment

is required to produce a given rotatory motion about the center of mass of the new system as about that of the pendulum, then the new system will for motions in a center plane be dynamically equivalent to the given pendulum, that is, if the two systems are moved in the same way the forces required to guide the motion will be equal. Since the two particles may have any ratio, provided the sum of their masses is equal to the mass of the pendulum, and since the line joining them may have any direction provided it passes through the center of mass, we may arrange them so that one of the particles corresponds to any given point of the pendulum, say, the point of suspension P (Fig. 13). The mass of

FIG. 13.



this particle and the position and mass of the other at Q will be determinate. The position of the second particle, Q, is called the Center of Oscillation. Now in the system of two particles, if one of them, P, is fixed, and the other, Q, allowed to swing under the action of gravity, we have a simple pendulum. For one of the particles, P, acts as the point of suspension, and the other, Q, is at an invariable distance from it, so that the connection between them is the same as if they were united by a string of length  $l = PQ$ .

Hence a pendulum of any form swings in exactly the same manner as a simple pendulum whose length is the distance from the center of suspension to the center of oscillation.

**INVERSION OF THE PENDULUM.**—Now let us suppose the system of two particles inverted, Q being made the point of suspension and P being made to swing. We have now a simple pendulum of the same length as before. Its vibrations will therefore be executed in the same time. But it is dynamically equivalent to the pendulum suspended by its center of oscillation.

Hence if a pendulum be inverted and suspended by its center of oscillation its vibrations will have the same period as before, and the distance between the center of suspension and that of oscilla-

tion will be equal to that of a simple pendulum having the same time of vibration.

It was in this way that Captain Kater determined the length of the simple pendulum which vibrates seconds.

He constructed a pendulum which could be made to vibrate about two knife edges, on opposite sides of the center of mass and at *unequal* distances from it.

By certain adjustments, he made the time of vibration the same whether the one knife edge or the other were the center of suspension. The length of the corresponding simple pendulum was then found by measuring the distance between the knife edges.

**ILLUSTRATION OF KATER'S PENDULUM.**—The principle of Kater's Pendulum may be illustrated by a very simple and striking experiment. Take a flat board of any form (Fig. 14), and drive a piece

FIG. 14.



of wire through it near its edge, and allow it to hang in a vertical plane, holding the ends of the wire by the finger and thumb. Take a small bullet, fasten it to the end of a thread and allow the thread to pass over the wire, so that the bullet hangs close to the board. Move the hand by which you hold the wire horizontally in the plane of the board, and observe whether the board moves forwards or backwards with respect to the bullet. If it moves forwards lengthen the string, if backwards shorten it till the bullet and the board move together. Now mark the point of the board opposite the center of the bullet and fasten the string to the wire. You will find that if you hold the wire by the ends and move it in any manner, however sudden and irregular, in the plane of the board, the bullet will never quit the marked spot on the board.

Hence this spot is called the center of oscillation, because when the board is oscillating about the wire when fixed it oscillates as if it consisted of a single particle placed at the spot.

It is also called the center of percussion, because if the board is at rest and the wire is suddenly moved horizontally the board will at first begin to rotate about the spot as a center.

**DETERMINATION OF THE INTENSITY OF GRAVITY.**—The most direct method of determining  $g$  is, no doubt, to let a body fall and find what velocity it has gained in a second, but it is very difficult to make accurate observations of the motion of bodies when their velocities are so great as 981 centimeters per second, and besides, the experiment would have to be conducted in a vessel from which the air has been exhausted, as the resistance of the air to such rapid motion is very considerable, compared with the weight of the falling body.

The experiment with the pendulum is much more satisfactory. By making the arc of vibration very small, the motion of the bob becomes so slow that the resistance of the air can have very little influence on the time of vibration. In the best experiments the pendulum is swung in an air-tight vessel from which the air is exhausted.

Besides this, the motion repeats itself, and the pendulum swings to and fro hundreds, or even thousands, of times before the various resistances to which it is exposed reduce the amplitude of the vibrations till they can no longer be observed.

Thus the actual observation consists not in watching the beginning and end of one vibration, but in determining the duration of a series of many hundred vibrations, and thence deducing the time of a single vibration.

The observer is relieved from the labor of counting the whole number of vibrations, and the measurement is made one of the most accurate in the whole range of practical science by the following method:

**METHOD OF OBSERVATION.**—A pendulum clock is placed behind the experimental pendulum, so that when both pendulums are hanging vertically the

bob, or some other part of the experimental pendulum, just hides a white spot on the clock pendulum, as seen by a telescope fixed at some distance in front of the clock.

Observations of the transit of "clock stars" across the meridian are made from time to time, and from these the rate of the clock is deduced in terms of "mean solar time."

The experimental pendulum is then set a swinging, and the two pendulums are observed through the telescope. Let us suppose that the time of a single vibration is not exactly that of the clock pendulum, but a little more.

The observer at the telescope sees the clock pendulum always gaining on the experimental pendulum, till at last the experimental pendulum just hides the white spot on the clock pendulum as it crosses the vertical line. The time at which this takes place is observed and recorded as the First Positive Coincidence.

The clock pendulum continues to gain on the other, and after a certain time the two pendulums cross the vertical line at the same instant in opposite directions. The time of this is recorded as the First Negative Coincidence. After an equal interval of time there will be a second positive coincidence, and so on.

By this method the clock itself counts the number,  $N$ , of vibrations of its own pendulum between the coincidences. During this time the experimental pendulum has executed one vibration less than the clock. Hence the time of vibration of the experimental pendulum

is  $\frac{N}{N-1}$  seconds of clock time.

When there is no exact coincidence, but when the clock pendulum is ahead of the experimental pendulum at one passage of the vertical and behind at the next, a little practice on the part of the observer will enable him to estimate at what time between the passages the two pendulums must have been in the same phase. The epoch of coincidence can thus be estimated to a fraction of a second.

**ESTIMATION OF ERROR.**—The experimental pendulum will go on swinging for some hours, so that the whole time to be

measured may be ten thousand or more vibrations.

But the error introduced into the calculated time of vibration, by a mistake even of a whole second in noting the time of vibration, may be made exceedingly small by prolonging the experiment.

For if we observe the first and the  $n$ th coincidence, and find that they are separated by an interval of  $N$  seconds of the clock, the experimental pendulum will have lost  $n$  vibrations, as compared with the clock, and will have made  $N-n$  vibrations in  $N$  seconds. Hence the time of a single vibration is  $T = \frac{N}{N-n}$  seconds of clock time.

Let us suppose, however, that by a mistake of a second we note down the last coincidence as taking place  $N+1$  seconds after the first. The value of  $T$  as deduced from this result would be

$$T' = \frac{N+1}{N+1-n}$$

and the error introduced by the mistake of a second will be

$$\begin{aligned} T' - T &= \frac{N+1}{N+1-n} - \frac{N}{N-n} \\ &= \frac{n}{(N+1-n)(N-n)} \end{aligned}$$

If  $N$  is 10000 and  $n$  is 100, a mistake of one second in noting the time of coincidence will alter the value of  $T$  only about one-millionth part of its value.

## CHAPTER VIII.

### UNIVERSAL GRAVITATION.

**NEWTON'S METHOD.**—The most instructive example of the method of dynamical reasoning is that by which Newton determined the law of the force with which the heavenly bodies act on each other.

The process of dynamical reasoning consists in deducing from the successive configurations of the heavenly bodies, as observed by astronomers, their velocities and their accelerations, and in this way determining the direction and the relative magnitude of the force which acts on them.

Kepler had already prepared the way for Newton's investigation, by deducing

from a careful study of the observations of Tycho Brahe the three laws of planetary motion which bear his name.

**KEPLER'S LAWS.**—Kepler's Laws are purely kinematical. They completely describe the motions of the planets, but they say nothing about the forces by which these motions are determined.

Their dynamical interpretation was discovered by Newton.

The first and second law relate to the motion of a single planet.

**LAW I.**—The areas swept out by the vector drawn from the sun to a planet are proportional to the times of describing them. If  $h$  denotes twice the area swept out in unit of time, twice the area swept out in time  $t$  will be  $h t$ , and if  $P$  is the mass of the planet,  $P h t$  will be the mass-area as defined in "Definition of a Mass-Area." Hence the angular momentum of the planet about the sun, which is the rate of change of the mass-area, will be  $P h$ , a constant quantity.

Hence, by "Moment of a Force about a Point," the force, if any, which acts on the planet must have no moment with respect to the sun, for if it had it would increase or diminish the angular momentum at a rate measured by the value of this moment.

Hence, whatever be the force which acts on the planet, the direction of this force must always pass through the sun.

**ANGULAR VELOCITY.**—Definition. The angular velocity of a vector is the rate at which the angle increases which it makes with a fixed vector in the plane of its motion.

If  $\omega$  is the angular velocity of a vector, and  $r$  its length, the rate at which it sweeps out an area is  $\frac{1}{2}\omega r^2$ . Hence,

$$h = \omega r^2$$

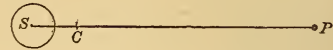
and since  $h$  is constant,  $\omega$ , the angular velocity of a planet's motion round the sun, varies inversely as the square of the distance from the sun.

This is true whatever the law of force may be, provided the force acting on the planet always passes through the sun.

**MOTION ABOUT THE CENTER OF MASS.**—Since the stress between the planet

and the sun acts on both bodies, neither of them can remain at rest. The only point whose motion is not affected by the stress is the center of mass of the two bodies.

FIG. 15.



If  $r$  is the distance  $SP$  (Fig. 15), and if  $C$  is the center of mass,  $\overline{SC} = \frac{Pr}{S+P}$

and  $\overline{CP} = \frac{Sr}{S+P}$ . The angular momentum of  $P$  about  $C$  is  $P \omega \frac{S^2 r^2}{(S+P)^2} = \frac{PS^2}{(S+P)^2 h}$ .

**THE ORBIT.**—We have already made use of diagrams of configuration and of velocity in studying the motion of a material system. These diagrams, however, represent only the state of the system at a given instant; and this state is indicated by the relative position of points corresponding to the bodies forming the system.

It is often, however, convenient to represent in a single diagram the whole series of configurations or velocities which the system assumes. If we suppose the points of the diagram to move so as continually to represent the state of the moving system, each point of the diagram will trace out a line, straight or curved.

On the diagram of configuration, this line is called, in general, the Path of the body. In the case of the heavenly bodies it is often called the Orbit.

**THE HODOGRAPH.**—On the diagram of velocity the line traced out by each moving point is called the Hodograph of the body to which it corresponds.

The study of the Hodograph, as a method of investigating the motion of a body, was introduced by Sir W. R. Hamilton. The hodograph may be defined as the path traced out by the extremity of a vector which continually represents, in direction and magnitude, the velocity of a moving body.

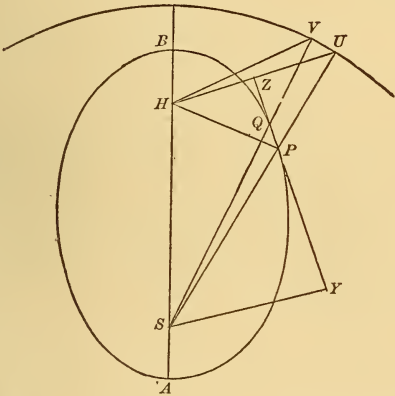
In applying the method of the hodograph to a planet, the orbit of which is

in one plane, we shall find it convenient to suppose the hodograph turned round its origin through a right angle, so that the vector of the hodograph is perpendicular instead of parallel to the velocity it represents.

**KEPLER'S SECOND LAW.—Law II.**—The orbit of a planet with respect to the sun is an ellipse, the sun being in one of the foci.

Let  $A P Q B$  (Fig. 16) be the elliptic orbit. Let  $S$  be the sun in one focus, and let  $H$  be the other focus. Produce  $S P$  to  $U$ , so that  $S U$  is equal to the transverse axis  $A B$ , and join  $H U$ , then  $H U$  will be proportional and perpendicular to the velocity at  $P$ .

FIG. 16.



For bisect  $H U$  in  $Z$  and join  $Z P$ ,  $Z P$  will be a tangent to the ellipse at  $P$ ; let  $S Y$  be a perpendicular from  $S$  on this tangent.

If  $v$  is the velocity at  $P$ , and  $h$  twice the area swept out in unit of time  $h = v \overline{S Y}$ .

Also if  $b$  is half the conjugate axis of the ellipse

$$\overline{S Y} \cdot \overline{H Z} = b^2$$

Now  $H U = 2 H Z$ ; hence

$$v = \frac{h}{2b} \overline{H U}$$

Hence  $H U$  is always proportional to the velocity, and it is perpendicular to its direction. Now  $S U$  is always equal to  $A B$ . Hence the circle whose center is  $S$  and radius  $A B$  is the hodograph of the planet,  $H$  being the origin of the hodograph.

The corresponding points of the orbit and the hodograph are those which lie in the same straight line through  $S$ .

Thus  $P$  corresponds to  $U$  and  $Q$  to  $V$ .

The velocity communicated to the body during its passage from  $P$  to  $Q$  is represented by the geometrical difference between the vectors  $H U$  and  $H V$ , that is, by the line  $U V$ , and it is perpendicular to this arc of the circle, and is therefore, as we have already proved, directed towards  $S$ .

If  $P Q$  is the arc described in unit of time, then  $U V$  represents the acceleration, and since  $U V$  is on a circle whose center is  $S$ ,  $U V$  will be a measure of the angular velocity of the planet about  $S$ . Hence the acceleration is proportional to the angular velocity, and this by "Angular Velocity" is inversely as the square of the distance  $S P$ . Hence the acceleration of the planet is in the direction of the sun, and is inversely as the square of the distance from the sun.

This, therefore, is the law according to which the attraction of the sun on a planet varies as the planet moves in its orbit and alters its distance from the sun.

**FORCE ON A PLANET.**—Since, as we have already shown, the orbit of the planet with respect to the center of mass of the sun and planet has its dimensions in the ratio of  $S$  to  $S + P$  to those of the orbit of the planet with respect to the Sun, if  $2a$  and  $2b$  are the axes of the orbit of the planet with respect to the sun, the area is  $\pi a b$ , and if  $T$  is the time of going completely round the orbit, the value of  $h$  is  $2\pi \frac{ab}{T}$

The velocity with respect to the sun is, therefore,

$$\pi \frac{a}{T b} \overline{H U}$$

With respect to the center of mass it is

$$\frac{S}{S+P} \pi \frac{a}{T b} \overline{H U}$$

The acceleration of the planet towards the center of mass is

$$\frac{S}{S+P} \pi \frac{a}{T b} U V$$

and the impulse on that planet whose mass is  $P$  is therefore

$$\frac{S \cdot P}{S+P} \frac{\pi a}{T^2} U V$$

Let  $t$  be the time of describing  $P Q$ , then twice the area  $S P Q$  is

$$h t = \omega r^2 t$$

$$\text{and } UV = 2a \omega t = 2a \frac{h}{r^2} t = 4\pi \frac{a^2 b}{T r^2} t.$$

Hence the force on the planet is

$$F = 4\pi^2 \frac{S \cdot P}{S+P} \frac{a^3}{T^2 r^2}$$

This then is the value of the stress or attraction between a planet and the sun in terms of their masses  $P$  and  $S$ , their mean distance  $a$ , their actual distance  $r$ , and the periodical time  $T$ .

INTERPRETATION OF KEPLER'S THIRD LAW.—To compare the attraction between the sun and different planets, Newton made use of Kepler's third law.

Law III.—The squares of the time of different planets are proportional to the cubes of their mean distances.

In other words  $\frac{a^3}{T^2}$  is a constant, say  $\frac{C}{4\pi^2}$

$$\text{Hence } F = C \frac{S \cdot P}{S+P} \frac{1}{r^2}$$

In the case of the smaller planets their masses are so small, compared with that of the sun, that  $\frac{S}{S+P}$  may be put equal to 1, so that  $F = C P \frac{1}{r^2}$

or the attraction on a planet is proportional to its mass and inversely as the square of its distance.

LAW OF GRAVITATION.—This is the most remarkable fact about the attraction of gravitation, that at the same distance it acts equally on equal masses of substances of all kinds. This is proved by pendulum experiments for the different kinds of matter at the surface of the earth. Newton extended the law to the matter of which the different planets are composed.

It had been suggested, before Newton proved it, that the sun as a whole attracts a planet as a whole, and the law of the inverse square had also been previously stated, but in the hands of Newton the doctrine of gravitation assumed its final form.

*Every portion of matter attracts every other portion of matter, and the stress between them is proportional to the product of their masses divided by the square of their distance.*

For if the attraction between a gramme of matter in the sun and a gramme of matter in a planet at distance  $r$  is  $\frac{C}{r^2}$

where  $C$  is a constant, then if there are  $S$  grammes in the sun and  $P$  in the planet the whole attraction between the sun and one gramme in the planet will be  $\frac{CS}{r^2}$ , and the whole attraction between the sun and the planet will be  $C \frac{SP}{r^2}$ .

Comparing this statement of Newton's "Law of Universal Gravitation" with the value of  $F$  formerly obtained we find

$$C \frac{S \cdot P}{r^2} = 4\pi^2 \frac{S \cdot P}{S+P} \frac{a^3}{T^2 r^2}$$

$$\text{or } 4\pi^2 a^3 = C(S+P)T^2.$$

AMENDED FORM OF KEPLER'S THIRD LAW.—Hence Kepler's Third Law must be amended thus:

The cubes of the mean distances are as the squares of the times multiplied into the sum of the masses of the sun and the planet.

In the case of the larger planets, Jupiter, Saturn, &c., the value of  $S+P$  is considerably greater than in the case of the earth and the smaller planets. Hence the periodic times of the larger planets should be somewhat less than they would be according to Kepler's law, and this is found to be the case.

In the following table the mean distances ( $a$ ) of the planets are given in terms of the mean distance of the earth, and the periodic time  $T$  in terms of the sidereal year:

(See Table on following page.)

It appears from the table that Kepler's third law is very nearly accurate, for  $a^3$  is very nearly equal to  $T^2$ , but that for those planets whose mass is less than that of the earth—namely, Mercury, Venus and Mars— $a^3$  is less than  $T^2$ , whereas for Jupiter, Saturn, Uranus and Neptune, whose mass is greater than that of the earth,  $a^3$  is greater than  $T^2$ .

POTENTIAL ENERGY DUE TO GRAVITATION.—The potential energy of the gravi-

Planet.	$a$	$T$	$a_3$	$T_2$	$a^3 - T_2$
Mercury..	0.387098	0.24084	0.0580046	0.0580049	— 0.0000003
Venus....	0.72333	0.61518	0.378451	0.378453	— 0.0000002
Earth.....	1.0000	1.00000	1.00000	1.00000	
Mars.....	1.52369	1.88082	3.53746	3.53747	— 0.00001
Jupiter....	5.20278	11.8618	140.832	140.701	+ 0.131
Saturn....	9.53879	29.4560	867.914	867.658	+ 0.256
Uranus....	19.1824	84.0123	7058.44	7058.07	+ 0.37
Neptune..	30.037	164.616	27100.0	27098.4	+ 1.6

tation between the bodies S and P may be calculated when we know the attraction between them in terms of their distance. The process of calculation by which we sum up the effects of a continually varying quantity belongs to the Integral Calculus, and though in this case the calculation may be explained by elementary methods, we shall rather deduce the potential energy directly from Kepler's first and second laws.

These laws completely define the motion of the sun and planet, and therefore we may find the kinetic energy of the system corresponding to any part of the elliptic orbit. Now, since the sun and planet form a conservative system, the sum of the kinetic and potential energy is constant, and therefore when we know the kinetic energy we may deduce that part of the potential energy which depends on the distance between the bodies.

**KINETIC ENERGY OF THE SYSTEM.**—To determine the kinetic energy we observe that the velocity of the planet with respect to the sun is by "Kepler's Second Law."

$$v = \frac{1}{2} \frac{h}{b^2} \overline{HU}$$

The velocities of the planet and the sun with respect to the center of mass of the system are respectively

$$\frac{S}{S+P} v \quad \text{and} \quad \frac{P}{S+P} v$$

The kinetic energies of the planet and the sun are therefore

$$\frac{1}{2} P \frac{S^2 v^2}{(S+P)^2} \quad \text{and} \quad \frac{1}{2} S \frac{P^2}{(S+P)^2} v^2$$

and the whole kinetic energy is

$$\frac{1}{2} \frac{S \cdot P}{S+P} v^2 = \frac{1}{4} \frac{S \cdot P}{S+P} \frac{h^2}{b^4} \overline{HU^2}$$

To determine  $v^2$  in terms of  $\overline{SP}$  or  $r$ , we observe that by the law of areas

$$v \cdot \overline{SY} = h = \frac{2\pi ab}{T} \quad \dots (1)$$

also by a property of the ellipse

$$\overline{HZ} \cdot \overline{SY} = b^2 \quad \dots (2)$$

and by the similar triangles HZP and SYP

$$\frac{\overline{SY}}{\overline{HZ}} = \frac{\overline{HP}}{\overline{SP}} = \frac{r}{2a-r} \quad \dots (3)$$

multiplying (2) and (3) we find

$$\overline{SY}^2 = \frac{b^2 r}{2a-r}$$

Hence by (1)

$$v^2 = \frac{4\pi^2 a^2 b^2}{T^2} \frac{1}{\overline{SY}^2} = \frac{4\pi^2 a^2}{T^2} \left( \frac{2a}{r} - 1 \right)$$

and the kinetic energy of the system is

$$\frac{4\pi^2 a^3}{T^2} \frac{S \cdot P}{S+P} \left( \frac{1}{r} - \frac{1}{2a} \right)$$

and this by the equation at the end of "Law of Gravitation" becomes

$$C \cdot S \cdot P \left( \frac{1}{r} - \frac{1}{2a} \right)$$

where C is the constant of gravitation.

This is the value of the kinetic energy of the two bodies S and P when moving in an ellipse of which the transverse axis is  $2a$ .

**POTENTIAL ENERGY OF THE SYSTEM.**—The sum of the kinetic and potential energies is constant, but its absolute value is by "Absolute Value of the Energy of a Body Unknown," and not necessary to be known.

Hence if we assume that the potential energy is of the form

$$K - C \cdot S \cdot P \frac{1}{r}$$

the second term, which is the only one depending on the distance,  $r$ , is also the only one which we have anything to do

with. The other term  $K$  represents the work done by gravitation while the two bodies, originally at an infinite distance from each other, are allowed to approach as near as their dimensions will allow them.

**THE MOON IS A HEAVY BODY.**—Having thus determined the law of the force between each planet and the sun, Newton proceeded to show that the observed weight of bodies at the earth's surface and the force which retains the moon in her orbit round the earth are related to each other according to the same law of the inverse square of the distance.

This force of gravity acts in every region accessible to us, at the top of the highest mountains and at the highest point reached by balloons. Its intensity, as measured by pendulum experiments, decreases as we ascend; and although the height to which we can ascend is so small, compared with the earth's radius, that we cannot from observations of this kind infer that gravity varies inversely as the square of the distance from the center of the earth, the observed decrease of the intensity of gravity is consistent with this law, the form of which had been suggested to Newton by the motion of the planets.

Assuming, then, that the intensity of gravity varies inversely as the square of the distance from the center of the earth, and knowing its value at the surface of the earth, Newton calculated its value at the mean distance of the moon.

His first calculations were vitiated by his adopting an erroneous estimate of the dimensions of the earth. When, however, he had obtained a more correct value of this quantity he found that the intensity of gravity, calculated for a distance equal to that of the moon, was equal to the force required to keep the moon in her orbit. He thus identified the force which acts between the earth and the moon with that which causes bodies near the earth's surface to fall towards the earth.

**CAVENDISH'S EXPERIMENT.**—Having thus shown that the force with which the heavenly bodies attract each other is of the same kind as that with which bodies that we can handle are attracted to the earth, it remained to be shown

that bodies such as we can handle attract one another.

The difficulty of doing this arises from the fact that the mass of bodies which we can handle is so small compared with that of the earth, that even when we bring the two bodies as near as we can the attraction between them is an exceedingly small fraction of the weight of either.

We cannot get rid of the attraction of the earth, but we must arrange the experiment in such a way that it interferes as little as is possible with the effects of the attraction of the other body.

The apparatus devised by the Rev. John Michell for this purpose was that which has since received the name of the Torsion Balance. Michell died before he was able to make the experiment, but his apparatus afterwards came into the hands of Henry Cavendish, who improved it in many respects, and measured the attraction between large leaden balls and small balls suspended from the arms of the balance. A similar instrument was afterwards independently invented by Coulomb for measuring small electric and magnetic forces, and it continues to be the best instrument known to science for the measurement of small forces of all kinds.

**THE TORSION BALANCE.**—The Torsion Balance consists of a horizontal rod suspended by a wire from a fixed support. When the rod is turned round by an external force in a horizontal plane it twists the wire, and the wire, being elastic, tends to resist this strain and to untwist itself. This force of torsion is proportional to the angle through which the wire is twisted, so that if we cause a force to act in a horizontal direction at right angles to the rod at its extremity, we may, by observing the angle through which the force is able to turn the rod, determine the magnitude of the force.

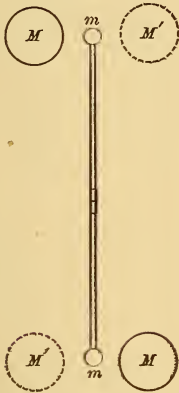
The force is proportional to the angle of torsion and to the fourth power of the diameter of the wire, and inversely to the length of the rod and the length of the wire.

Hence, by using a long fine wire and a long rod, we may measure very small forces.

In the experiment of Cavendish two spheres of equal mass,  $m$ , are suspended

from the extremities of the rod of the torsion balance. We shall for the present neglect the mass of the rod in comparison with that of the spheres. Two larger spheres of equal mass,  $M$ , are so arranged that they can be placed either at  $M$  and  $M$  or at  $M'$  and  $M'$ . In the former position they tend by their attraction on the smaller spheres,  $m$  and

FIG. 17.



$m$ , to turn the rod of the balance in the direction of the arrows. In the latter position they tend to turn it in the opposite direction. The torsion balance and its suspended spheres are enclosed in a case, to prevent their being disturbed by currents of air. The position of the rod of the balance is ascertained by observing a graduated scale as seen by reflection in a vertical mirror fastened to the middle of the rod. The balance is placed in a room by itself, and the observer does not enter the room, but observes the image of the graduated scale with a telescope.

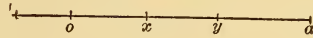
**METHOD OF THE EXPERIMENT.**—The time,  $T$ , of a double vibration of the torsion balance is first ascertained, and also the position of equilibrium of the centers of the suspended spheres.

The large spheres are then brought up to the positions  $MM$ , so that the center of each is at a distance from the position of equilibrium of the center of the suspended sphere.

No attempt is made to wait till the vibrations of the beam have subsided, but the scale-divisions corresponding to the extremities of a single vibration are observed, and are found to be distant  $x$

and  $y$  respectively from the position of equilibrium. At these points the rod is, for an instant, at rest, so that its energy is entirely potential, and since the total energy is constant, the potential energy corresponding to the position  $x$  must be equal to that corresponding to the position  $y$ .

FIG. 18.



Now if  $T$  be the time of a double vibration about the point of equilibrium  $O$ , the potential energy due to torsion when the scale reading is  $x$  is by "Potential Energy of the Vibrating Body"

$$\frac{2\pi^2 m}{T^2} x^2$$

and that due to the gravitation between  $m$  and  $M$  is by "Potential Energy of the System"

$$K - C \frac{m M}{a - x}$$

The potential energy of the whole system in the position  $x$  is therefore

$$K - C \frac{m M}{a - x} + \frac{2\pi^2 m}{T^2} x^2$$

In the position  $y$  it is

$$K - C \frac{m M}{a - y} + \frac{2\pi^2 m}{T^2} y^2$$

and since the potential energy in these two positions is equal,

$$C m M \left( \frac{1}{a - y} - \frac{1}{a - x} \right) = \frac{2\pi^2 m}{T^2} (y^2 - x^2)$$

Hence

$$C = \frac{2\pi^2}{M T^2} (x + y) (a - x) (a - y)$$

By this equation  $C$ , the constant of gravitation, is determined in terms of the observed quantities,  $M$  the mass of the large spheres in grammes,  $T$  the time of a double vibration in seconds, and the distances  $x$ ,  $y$  and  $a$  in centimeters.

According to Baily's experiments,  $C = 6.5 \times 10^{-8}$ . If we assume the unit of mass, so that at a distance unity it would produce an acceleration unity, the centimeter and the second being units, the unit of mass would be about  $1.537 \times 10^7$  grammes, or 15.37 tonnes. This unit of mass reduces  $C$ , the constant of gravitation, to unity. It is

therefore used in the calculations of physical astronomy.

**UNIVERSAL GRAVITATION.**—We have thus traced the attraction of gravitation through a great variety of natural phenomena, and have found that the law established for the variation of the force at different distances between a planet and the sun also holds when we compare the attraction between different planets and the sun, and also when we compare the attraction between the moon and the earth with that between the earth and heavy bodies at its surface. We have also found that the gravitation of equal masses at equal distances is the same whatever be the nature of the material of which the masses consist. This we ascertain by experiments on pendulums of different substances, and also by a comparison of the attraction of the sun on different planets, which are probably not alike in composition. The experiments of Baily on spheres of different substances placed in the torsion balance confirm this law.

Since, therefore, we find in so great a number of cases occurring in regions remote from each other that the force of gravitation depends on the mass of bodies only, and not on their chemical nature or physical state, we are led to conclude that this is true for all substances.

For instance, no man of science doubts that two portions of atmospheric air attract one another, although we have very little hope that experimental methods will ever be invented so delicate as to measure or even to make manifest this attraction. But we know that there is attraction between any portion of air and the earth, and we find by Cavendish's experiment that gravitating bodies, if of sufficient mass, gravitate sensibly towards each other, and we conclude that two portions of air gravitate towards each other. But it is still extremely doubtful whether the medium of light and electricity is a gravitating substance, though it is certainly material and has mass.

**CAUSE OF GRAVITATION.**—Newton, in his *Principia*, deduces from the observed motions of the heavenly bodies the fact that they attract one another according to a definite law.

This he gives as a result of strict dynamical reasoning, and by it he shows how not only the more conspicuous phenomena, but all the apparent irregularities of the motions of these bodies are the calculable results of this single principle. In his *Principia* he confines himself to the demonstration and development of this great step in the science of the mutual action of bodies. He says nothing about the means by which bodies are made to gravitate towards each other. We know that his mind did not rest at this point—that he felt that gravitation itself must be capable of being explained, and that he even suggested an explanation depending on the action of an etherial medium pervading space. But with that wise moderation which is characteristic of all his investigations, he distinguished such speculations from what he had established by observation and demonstration, and excluded from his *Principia* all mention of the cause of gravitation, reserving his thoughts on this subject for the "Queries" printed at the end of his "Opticks."

The attempts which have been made since the time of Newton to solve this difficult question are few in number, and have not led to any well-established result.

**APPLICATION OF NEWTON'S METHOD OF INVESTIGATION.**—The method of investigating the forces which act between bodies which was thus pointed out and exemplified by Newton in the case of the heavenly bodies, was followed out successfully in the case of electrified and magnetized bodies by Cavendish, Coulomb, and Poisson.

The investigation of the mode in which the minute particles of bodies act on each other is rendered more difficult from the fact that both the bodies we consider and their distances are so small that we cannot perceive or measure them, and we are therefore unable to observe their motions as we do those of planets, or of electrified and magnetized bodies.

**METHODS OF MOLECULAR INVESTIGATIONS.**—Hence the investigations of molecular science have proceeded for the most part by the method of hypothesis,

and comparison of the results of the hypothesis with the observed facts.

The success of this method depends on the generality of the hypothesis we begin with. If our hypothesis is the extremely general one that the phenomena to be investigated depend on the configuration and motion of a material system, then if we are able to deduce any available results from such an hypothesis, we may safely apply them to the phenomena before us.

If, on the other hand, we frame the hypothesis that the configuration, motion, or action of the material system is of a certain definite kind, and if the results of this hypothesis agree with the

phenomena, then, unless we can prove that no other hypothesis would account for the phenomena, we must still admit the possibility of our hypothesis being a wrong one.

**IMPORTANCE OF GENERAL AND ELEMENTARY PROPERTIES.**—It is therefore of the greatest importance in all physical inquiries that we should be thoroughly acquainted with the most general properties of material systems, and it is for this reason that in this book I have rather dwelt on these general properties than entered on the more varied and interesting field of the special properties of particular forms of matter.

## THE DRAINAGE SYSTEM OF PHILADELPHIA.

By RUDOLPH HERING.

Condensed from a Paper read at the Meeting of the Engineers' Club of Philadelphia.

It is a well-known fact that a large percentage of sickness in our city is due to defective drainage. The importance of considering a remedy is, therefore, apparent. It is my purpose to give a general idea of the ways in which our houses and streets are drained, and then to point out some of the defects, together with their remedies, which, if not securing a complete immunity from disease, would remove a powerful agency for the evil.

The house drains form the most important part of the drainage system. Upon the care bestowed upon them will, in a great measure, depend the ultimate success of the whole, from a sanitary point of view.

The whole matter is left to the plumbers. Although they may be excellent and conscientious workmen, they are generally not versed in the principles of the science governing the design and executing them out by the unwillingness of the property owners to pay them. Col. Waring has formulated the requirements of a perfect system of house drainage, as follows:

Allow no organic decomposition to take place within or near the dwelling

or within any drain or pipe connected with it, under conditions favorable to the propagation of unhealthful influences.

Allow no air that has once been inside of a drain or soil pipe to enter the house under any conditions.

Let us see how far our house-drainage answers this formula. We have in the main three different systems.

First. The drainage of the soil-pipe discharges into a cesspool or well, and the waste waters are conveyed on the surface into the street gutters. This is the oldest and, until recently, most used, and is still designed for the many new houses built on streets without sewers. In old houses the wells are generally in the cellar, in the new ones they are in the yard. All wells being lined with bricks laid dry allow the liquid to soak away into the adjoining ground. We therefore do allow decomposition to take place in the well within or near our dwellings, and this under conditions favorable for spreading disease, and also allow air from the cesspool, especially when in the cellar, to rise directly into the house. The surface discharge of waste water is not injurious to the health because it facilitates oxydation. But it is annoying and disagreeable, partly

because we see it constantly, partly because it covers the sidewalks with ice in winter and endangers the comfort of pedestrians.

Second. All drainage is conveyed underground to the sewer, including the overflow from the cesspool. This system is the most common. The old cesspool, still used as before, is connected with the sewer, generally by an eight-inch terra cotta pipe. From this a soil pipe, usually of cast iron, four inches in diameter, is carried up to the water closets. Waste pipes, not over one-and-a-half inches in diameter, run from the kitchen, bath-room and washstands into the soil pipe or main pipe, but generally in a manner which requires the shortest length of pipe, whether this is beneficial to the inhabitants or not. The spouts are generally carried into the main pipe. Nearly always traps are put in under each place where refuse is received, as under the water closet, sinks and washstands; sometimes an additional main trap is placed where the pipe enters the cellar. The intermediate air-locked portion is connected with some pipe leading to the roof, generally a rain waterspout. Hardly one house in a hundred has its soil pipes ventilated properly, and hardly ever the waste pipes. No provision is ever made to allow fresh air to enter and circulate through the pipes. The work itself is generally done very badly, especially in the bonus houses. It is amazing how recklessly the drains are put into some houses, accomplishing in reality, in a far greater degree, just what they are intended to avoid.

But let us see the defects clearly by applying our formula. Decomposition is allowed to take place in the cesspools under conditions favorable to disease, as the sewage remains there a long time before the overflow carries it away, and the contaminated air, when originating in the cellar, rises immediately into and through the house. The absence of ventilation allows decomposition in the pipes, and, as the joints and fittings are often poorly made, allowing an escape, the poisonous gas reaches us often also directly from this source. During a heavy rain storm the sewer receives much water, the air is therefore forced out, and, as the manhole covers are tight, it blows

out the weakest traps and enters our houses. It can be detected by the bubbling noise in the washstands and water closets.

Third. All drainage is conveyed directly into the sewer, solely through the pipes without having any cesspool on the premises. This is the latest system and the best. It leads, when properly designed and built, all refuse matter as directly and as rapidly as possible away from the premises. But the details are the same as before, with the same objectional features, excepting those of the cesspool. With the absence of proper ventilation, and of a most careful design and execution of all its details, it is impossible to have a system answering the requirements of health.

Why have we these imperfections? Because there is an entire absence of municipal regulations governing the details of house drainage. Proprietors and plumbers have their own way and carry out their own ideas. Water pipes are laid according to regulations. Gas pipes are carefully inspected as to their sizes, directions, bends, position, &c. But drain pipes, the contents of which have such a powerful influence on the state of our health, receive no attention whatever. The requirement, therefore, is that we should have municipal regulations in accordance with the latest information that the respective sciences furnish us; and the second that we should have an efficient system of carrying them out, by intelligent management, by licensed plumbers and by inspectors placed under bond.

Sewers are to collect the discharge from the dwellings and washings from the streets, and to convey them to places where they can do no harm. A sewer will never be anything but a powerful enemy in our midst, and if not under perpetual supervision will be able any day to proclaim a victory in some home. To reduce the evil to a minimum, it is absolutely necessary that all the works should be designed, built and maintained according to the latest and most approved methods of the science of sanitary engineering. The requirements of a perfect system of sewerage may be stated as follows:

A. To allow no decomposition of organic matter to take place under con-

ditions favorable to the propagation of unhealthful influences.

This can be accomplished under the following conditions.

First. Water-tight sewers.

Second. Rapid reception and conveyance, together with effectual discharge of all sewage and storm water.

Third. Proper ventilation.

B. To be readily accessible in all its parts.

This is accomplished by a sufficient number of man-holes and lamp-holes, serving at the same time as ventilators.

C. To be built with a uniformity of design and in the best practicable manner.

D. To be designed with reference to economy of first cost and maintenance.

We will now describe our sewers, aggregating in length nearly two hundred miles, state wherein they do not fulfill these requirements, and how the defects may be greatly improved.

The branch sewers have a clear diameter of 3 feet, and are originally circular in form. They are built of a 4" ring of brick, the invert being usually laid dry and the arch built with mortar. After several years they are found to be more or less elliptical, the long axis being horizontal. Whenever well built this should not occur. If the ellipse is too flat, then the arch falls down. If it does not come to this, it has a form which gives for the usual flow about the greatest surface of friction for the amount of water, precisely the opposite of what is desirable for a perfect sewer, as the velocity is thereby diminished and a deposit caused. As the bricks are not laid carefully, the sides are very rough, which impairs the velocity of the flow, and allows solid particles to adhere and decompose.

There has been no systematic provision for ventilation. Man-holes are built into the work at intervals of from 200 to 400 feet, but are covered with tight-fitting cast-iron lids.

The connections of the house drains with the sewers are made by the plumbers. The city reserves the right to inspect the connections; but, judging from the fact that by far the most breaks in our small sewers occur just where such connections have been put in, they cannot have been done very perfectly. We see

that the most important of the above requirements have not been fulfilled. Our sewers are not water-tight, but allow sewage to soak into and penetrate the ground instead of taking it away. The flat bottom and the roughness of the sides reduce the velocity considerably, which either prevents the removal of the sewage before decomposition or actually causes a deposit. There is no ventilation, no ingress or egress of air, except by forcing the traps that lead into our dwellings. They are not built in the best practical manner, nor with reference to the cost of maintenance, which has been immense. About \$100,000 are yearly expended to keep our sewers in repair.

A system answering the requirements to a far greater degree, would be a system of 12 and 15-inch drain pipes instead of 3 feet sewers. Their capacity is ample for the heaviest storms for a length of several squares. The whole city of Saratoga, including the drainage area of a small run, has been effectually drained by a single 3 feet sewer. Where the pipes are well laid they have given satisfaction. They are extensively used in the best drained cities of the world. Where badly laid, however, they are even worse than our present sewers on account of not being as accessible. The main advantages are as follows:

First. They are water tight when properly jointed.

Second. Owing to their smoothness they will rapidly receive and convey all sewage when carefully laid to the proper grades and curves. They will admit of a smooth and neat connections with the house drains, thereby likewise increasing the velocity.

Third. They can be properly ventilated. At present the prevailing opinion among sanitary engineers is that all sewers should have free communication with the atmosphere as often as possible through open manholes. The oftener the air in the sewer can be replaced by a fresh supply the better. The man-holes being the same a twelve-inch pipe would stand a much better chance of having its air renewed, as it contains only one-ninth as much as a three-foot sewer. As the flow is more rapid it would draw the air with it and help the exchange. As there is a quicker discharge and a smaller

surface exposed to the air there will be less occasion to decompose and vitiate the air.

Fourth. They can be readily accessible when properly built and provided with manholes.

Fifth. There is no experience, as far as engineering is concerned, that prevents them from being laid in a perfect manner; that is, with regular grades and lines, with perfectly tight joints, and with such foundations as will make an uneven settlement, breaking the pipes or joints very rare, if not impossible.

Sixth. They are as cheap as a three-feet brick sewer. The cost of maintenance would be much less, and they could be thoroughly cleaned by a stream from a fireplug.

The main sewers collect the discharges from the branch sewers, and convey them to the rivers.

By regulation the size of a main sewer shall be sufficient to enable it to discharge an amount of storm water equal to a rainfall of one inch per hour. The consequence is that our sewers are extremely large, and, as I believe can be shown, entirely too large. The matter is a serious one, as it involves a great amount of money. If the provision for a half-inch rainfall would be ample the cost of the sewers of our city would be diminished at least one million of dollars. Boston, Providence, New York and Philadelphia have, according to the Smithsonian contributions, about the same rainfall when the heaviest showers occur.

In Boston the sewers are calculated for one quarter inch rainfall, and have been found satisfactory. In Providence which has the best drainage system in the United States, they allow for a little over one half of an inch of rainfall and are perfectly well satisfied.

In New York, however, they calculate for one inch. But were the city not so peculiarly situated, being a long, narrow strip of ground between two rivers, which gives but small drainage areas, and, consequently, comparatively small and inexpensive sewers, their attention would likely have been drawn to the subject more closely on account of the vast expanse. In Philadelphia we also calculate for one inch of rainfall to reach our sewers. Our drainage areas being

very large, the sewers, therefore, become immense. Leaving out the Wissahickon and Tacony creeks which two creeks ought never to be turned into a sewer, we have the Mill creek, draining about 3000 acres, requiring a sewer 20 feet in diameter and about 2 miles in length; the Heart creek, draining about 2000 acres, making the sewer from 13 to 16½ feet in diameter for 2 miles; the Honey Run sewer will drain over 4000 acres and at six miles above its probable outlet has already a diameter of fourteen feet, and so on. It can readily be seen what stupendous works we have in prospect. Roughly estimated, we will need at least \$3,000,000 to provide for main sewers probably becoming necessary in the next twenty years. How important therefore, is the question of size! From personal observations I believe that we have never had a shower sufficiently heavy to fill any of our largest sewers, provided they were not tide-locked and otherwise improperly built, except, perhaps, at the entrances, where the water is naturally dammed up. Experience tells us that only a portion of the rain-water finds its way into the sewers. The rest is either evaporated or absorbed, especially when we have the heaviest storms.

We also know that it takes considerable time for the rain water to reach the sewer and to flow through it, the storms often ceasing in the meantime. As main sewers are massive and strong, they can stand a considerable upward pressure in case they should be completely filled. From all these facts it is evident, I believe, that we could reduce the size of our sewers perhaps one half without running any risk. And if there should be some damage to pay occasionally for the flooding of a few cellars, which is not even probable, if safeguards are provided, would it not be more economical than to spend more than a million for an increased size? Here also can be said, the smaller the sewers the easier it is to ventilate them, and the greater will be the velocity for the same amount of sewage and the more effectual the discharge.

The *shape* of our main sewers is circular; occasionally they have a flat bottom. There should be a distinction made in the design between arch and

invert. The arch must resist external pressure, for which the science of statics gives readily the best form for any conditions. The earlier sewers have not been satisfactory in this respect. Only those built during the last two or three years have answered the requirements of stability and good workmanship. The shape of the invert should be governed by another element. That is, in order to be self-cleaning the sewers should give the greatest possible velocity to the ordinary flow. This can be done best by the egg-shaped section, which is extensively used in the best drained cities, and answers admirably. In Philadelphia it has not been used. The results from not doing so can be observed in many sewers.

Ventilation has not yet been systematically introduced. How much study

is still required to obtain a satisfactory conclusion may be seen from the fact that in London large ventilating shafts have proved a failure, and in Frankfort, the best drained city in the world, they have been a success.

The whole subject, especially the house drainage, needs sincere and early attention and study. But, more than that, it needs *action*. Much has been said by physicians and engineers, but almost nothing has been done. We hear continually something said about our bad drainage, but few seem to know just where the technical imperfections are. As I have given the matter some study, and as it seems to be justly of general interest to the community at present, I thought it a seasonable subject to present to you this evening.

## THE DRAINAGE OF LAKE FUCINO.

By A. BRISSÉ AND L. DE ROTROU.

From the "Abstracts" of the Institution of Civil Engineers.

FUCINO was the largest lake in Central or Southern Italy, situated in the province of Aquila. It covered the greater part of a vast table land belonging to the territory of the subprefecture of Avezzano, a small town rising at a little distance from its shores. This table-land is one of the largest to be met with in the central part of the Apennines, and is surrounded on all sides by spurs of the main chain of mountains, thus forming a vast basin entirely separated from the adjacent valleys, so that the rain waters falling within its limits possessed no outlet by which to discharge themselves into the neighboring rivers. The area of this basin is 173,000 acres, and the surface waters of the lake on the 10th of June, 1861, stood at 2,094 feet above sea-level. In consequence of the peculiar conformation of this basin, having no communication with any of the adjacent valleys, and the waters collecting in it having no subterranean or other outlet—no means of escape, in fact, but by evaporation or absorption—it frequently happened that, owing to excess or deficiency of rainfall, the level

of the lake either rose or fell beyond its normal levels; in the former case inundating the valleys on its borders, and in the latter producing unhealthiness from its exposed banks. Julius Cæsar was the first to conceive the idea of draining the lake; it was attempted by Claudius, and the works which he caused to be executed were considered by Pliny as the most extraordinary of that age. The attempt of Claudius was renewed by Trajan and by Hadrian, and in the middle ages by Frederic II., perhaps also by Alphonso I. of Aragon, and by several sovereigns of Naples but always in vain.

The area of the lake naturally fluctuated from time to time, but its average dimensions were about 37,050 acres. In form it was very nearly elliptical, its greater axis, running from northeast to southeast, was about 12.4 miles long, the shorter one nearly 7 miles. Its bottom sloped very gently downwards from west to east, and at about 7.4 miles from the head of the tunnel constructed by the Romans to drain the lake the bottom was very nearly level, and constituted the lowest part of the basin. Beyond

this level part, the bed rose again towards the east, but with a much steeper gradient. Owing to the amount of earth annually washed into the lake, it was calculated that its bed had risen 15.65 feet since the time of the Emperor Claudius, when its depth is assumed to have been about 53.723 feet.

The most important, as well as the nearest, of the valleys situated on the other side of the mountains which gird the Fucino basin, is that of the Liris, which, to the west, runs parallel for a certain distance with the plateau of the lake, but at a lower level. The river is about  $3\frac{3}{4}$  miles in a straight line from the lake but between the two there is a mountain, Mount Salviano, and another plain called the "Campi Palentini," higher than the lake. As the position of the latter precluded the possibility of making an open cutting between it and the river Liris, the Emperor Claudius determined to excavate a tunnel through Mount Salviano, at about 984 feet below its summit, and under the Palentine fields at an average depth below the surface of 328 feet, in order to discharge the water from the Fucino into the river Liris at a sufficient height above the latter to enable it, even when in flood, to receive the water from the mouth of the tunnel. This tunnel had its outfall at a level of 41.487 feet above the Liris, and was constructed on a gradient of about  $1\frac{1}{2}$  in 1,000. As far as could be judged by the ruins of the tunnel, which it was found necessary to demolish in order to replace it by the tunnel of Prince Torlonia, it had a cross section of 11.9 square yards, and its head is supposed to have been somewhere about  $3\frac{3}{4}$  feet above the then bottom of the lake. In the construction of this tunnel the Romans sank about forty shafts, twenty nine between the foot of Mount Salviano and the river Liris, and the remainder between the mountain and the lake, ranging from 57.72 feet to over 400 feet in depth. One of these shafts which was opened whilst constructing the Torlonia tunnel, was found to be square, each side measuring 14.16 feet and supported in the middle by strong cross beams dividing the shaft into four equal compartments. The tunnel of Claudius was 6,178.59 yards in length and it passed through the following soils

in its course from its outfall to its head :

	Yards.
Compact limestone rock.....	708.26
Detached blocks accumulated on the slope of the compact rock.....	251.30
Pudding stone, composed of rolled gravel embedded in calcareous cement..	944.35
Detached blocks.....	85.25
Compact limestone.....	826.30
Detached blocks.....	118.04
Clay and sand.....	751.98
Detached blocks.....	118.04
Compact limestone.....	891.88
Broken rocks in the center of the mountain.....	426.27
Compact limestone.....	453.59
Softer limestone.....	555.24
Clay.....	48.09

Total..... 6,178.59

It will be sufficient here to state that although water is said to have flowed through this channel, its inefficiency soon proved itself, and an accident closed up the tunnel altogether for all practical purposes.

In 1854, however, Prince Alexander Torlonia decided to carry out the drainage of the lake at his own expense, and he entrusted its execution to M. de Montricher, who was assisted by M. Henri Bermont and M. Alexander Brisse.

In determining the section to be given to the Torlonia tunnel the conditions of possible rainfall and the capacity of the Liris to receive the discharge were considered. On the former point much uncertainty existed, but M. de Montricher came to the conclusion that under no circumstances should a volume of water greater than 11,000 gallons per second be discharged into the Liris, and this quantity was also found to agree with that of the supply of the lake during a hypothetical rising of 5 feet 10 inches in two months. M. de Montricher, therefore, resolved upon a tunnel having a cross section of 216 square feet and a general slope of 1 in 1,000, and following generally the Roman tunnel which might thus be utilized as a headway.

The new tunnel is egg-shaped in section, truncated at its small base, and resting on an invert 9.3 feet in span, with a versed sine of 9.6 inches. The greater axis measured 19 feet from the bottom of the invert to the crown of the arch; the lesser one, 13.1 feet at a height of  $12\frac{1}{2}$  feet above the bottom of the

invert, which gives a profile having an area of 211 square feet. The slope is generally 1 in 1,000, and with a depth of water of 17.25 feet upon the invert, the discharge is 11,000 gallons per second. The datum point was fixed at the outfall of the tunnel, 33 feet above the bed of the river and  $8\frac{1}{2}$  feet below the Roman invert at that place. The deepest part of the lake was at this time 48 feet above datum, and at a distance of 11 miles from the bench-mark at the outfall. The surface of the lake was 98 feet above datum, and its depth 50 feet. The invert of the Torlonia tunnel, at its outfall on the Liris, was placed 6 feet above datum; or 2.65 feet lower than the Roman tunnel at that spot. Thence it is carried at a slope of 2 in 1,000 for the first 393 yards, and at 1 in 1,000 for the rest of its length.

The works were commenced by the construction of a dam, to be cut off the waters of the lake from the head of the Roman tunnel. This dam was formed by two parallel arms, 240 yards distant from each other, and connected by a curve of 120 yards radius, its total length being 1,640 yards. Its top was protected by a strong stone revetment, and for further protection an inner dam was also constructed, with a space between the two of about 32 acres. About 196,200 cubic yards of earth and 39,300 cubic yards of stone were employed in the constructing of these works. The tunnel was commenced at the outfall towards the end of 1855, the greater part of it being constructed with hewn stone, brickwork being only occasionally introduced. Considerable difficulties were experienced during the progress of the work, owing to the quantity of water met with in the shafts, the workmen having sometimes to labor in water and mud up to their waists. As soon as the first 5,084 yards of tunnel had been completed, a communication was opened with the old Roman tunnel, into which the waters of the lake were directed, in order to reduce the head before completing the works. This preliminary draining lasted four hundred and seventeen days, and reduced the level of the lake by 14 feet, after which the tunnel was continued as far as the head of the Roman work, when a second draining of the lake was commenced, a canal

being cut to direct the waters of the lake to the tunnel. The surface of the lake, at the completion of this draining was lowered another 25 feet, its depth reduced to  $18\frac{1}{2}$  feet, and its area to 23,230 acres. The tunnel was completed in November 1869 to a length of 6,887 yards, of which 2,813 yards were excavated through the compact rock without revetment, 344 yards through pudding stone, and lined with brick, and 3,729 yards through clay, detached rocks, &c., and lined with strong masonry of hewn stone. For its construction twenty-eight shafts were sunk or repaired, having an aggregate length of 1,560 yards, and two inclined galleries, together 568 yards long. The deepest of the shafts made use of for removing the excavated material was 154 feet, and the shallowest 55.44 feet. Twelve of the twenty-eight shafts were above 279 feet in depth. For the last 22 yards of its length the tunnel gradually widens and at its mouth is divided by a cutwater into two small tunnels, each of which is fitted with a sluice gate; and 7 feet advance of this is the real entrance, consisting of a semicircular arch in springing from vertical side walls 197 feet apart, and in front of this again is a regulating basin. In order to drain the lower part of the lake, a canal was excavated leading to the head of the tunnel, having the same capacity as the tunnel itself, and a slope of 1 in 6,959, its bottom width being 49.21 feet, and its sides having a batter of  $45^\circ$ . This canal,  $8\frac{1}{4}$  miles in length, was formed by dredging, effected whilst the waters were still being drained off from the lake. The further works undertaken to complete the reclamation of land consisted of 130 miles of roads, 62 miles of canals and drains (inclusive of the main canal, but exclusive of the tunnel), and  $402\frac{1}{4}$  miles of ditches, and the land reclaimed amounts to 35,012 acres.

The total aggregate cost of this work to Prince Torlonia was 43,137,208 francs or about £1,800,000. Of this a little over £1,000,000 sterling was the cost of the tunnel, canal, and drainage works generally; £600,000 for compensations, roads, bridges, drains, and incidental expences, including 5 per cent. interest on capital during construction of the works, and something under £200,000

for preliminary expenses, purchase of concession, contribution towards improving the channel of the river Liris, and other minor incidental charges.

It is calculated that, by the increase in value of land previously cultivated, the drainage of Lake Fucino has added £160,000 to the wealth of the proprie-

tors along its shores, which it is expected in the course of a few years, will still further increase. In addition to this there remains the 35,012 acres reclaimed from the lake, the proprietary of which is vested in Prince Torlonia in return for his expenditure in the construction of the works.

## PROGRESS IN FIELD-GUNS.

From "The Engineer."

SUFFICIENT has transpired to show that, in their efforts to produce an improved field-gun, the authorities connected with the Royal Gun Factories have been gaining fresh light of great value as to the conditions of success. One element of accuracy in the shooting of breech-loaders has been very clearly ascertained and will be appropriated for the benefit of muzzle-loaders. When a gun is loaded from the rear the shot of course goes in first. This being the process, it has been necessary to fix the position of the shot by some mechanical arrangement, independently of the powder charge. Hence the powder chamber has been made to retain an unvarying capacity, and it has been perfectly practicable for each round to possess exactly the same elements. Consequently, when shooting for accuracy, a very neat diagram has been made, it being possible to lodge the several shots very close together. The muzzle-loader having its shot rammed down upon its cartridge, has been subject to varying degrees of pressure on the latter, and a varying position of the shot. Weight for weight any number of rounds might be exactly the same but the capacity of the powder chamber might be rarely twice alike. What this involves has been strikingly apparent in the experiments with the 80-ton gun. A gun is loaded not only with powder and shot but also with air, and the proportion of the latter affects the burning of the cartridge, the pressure set up in the gun, and the velocity imparted to the projectile. If a breech-loader has the same weight of powder and shot in a succession of rounds, it also has the same bulk of air behind the

shot. The makers and advocates of breech-loaders were apparently unconscious until lately of the advantage which they gained in this respect. But the matter is well understood by Herr Krupp at the present time. The principle being apprehended, there is no reason why it should not be applied to muzzle-loading guns, and this is the point which has now been reached. The varying air space in the different rounds probably accounted for the defective shooting at high angles during the Eastbourne experiments.

There is no need for any more of this, and the new field-gun will unquestionably be provided with better appliances for securing a fixed capacity in the powder-chamber. It is also possible that we may see some change in the position of the copper gas-check. Herr Krupp places his gas-check—at least in some of his recent guns—a short distance in advance of the base of the shot, the gas check being a ring or band instead of a disc. As this tends to weaken a projectile, it would be an objection in an armor-piercing shot or shell; but the objection would not apply in the case of field artillery. There are certain advantages in such an application of the gas-check, and though there may be some mechanical difficulty in employing this method with muzzle loaders, it would seem that something of the kind can be effected. As for the rifling, it is unquestionable that we are bidding good-bye to the studs, and that rotation is to be obtained henceforth from the gas-check, in conjunction with the polygroove system.

Until very recently the breech-loader had an advantage over the muzzle-loader

in the position of a powder chamber. The enlargement of the bore at the lower end of a rifled breech-loader was not adopted originally for the sake of using a shorter cartridge or a larger charge, but in order to make room for the entrance of the lead-coated projectile.

Afterwards it was discovered that other benefits accrued. The action of the powder charge in a gun not being so well understood as it is now, it was thought that if a muzzle-loader were chambered, it would be necessary to have a cartridge of peculiar construction, so that when rammed home it should expand laterally and occupy the enlarged diameter. But the big gun has taught us that it is well to have some amount of space unoccupied in the powder-chamber, and accordingly there is no peculiar difficulty in the use of a chambered muzzle-loader. In fact, if it is thought desirable to make the cartridge swell out so as to fill the diameter of the chamber, it becomes necessary to create an air-space inside the cartridge by means of a hollow cone or similar contrivance, which, in the case of the 80-ton gun, is utilized for the transmission of a flash through an axial vent, whereby the cartridge is fired centrally, thereby preventing or diminishing those waves of pressure which act locally with abnormal force.

Two new field-guns, designed and manufactured by Sir W. G. Armstrong & Co., have been fired at the proof butts on the Government ground at Woolwich,

and are about to be tried at Shoeburyness for range and accuracy. One is a muzzle-loader, and the other a breech-loader. The trials with the experimental 12-pounder of the Royal Gun Factories are still in progress, and very important results have been achieved. How these will compare with the performance of the Elswick guns remains to be seen. The gun itself is not the only question. There are many details connected with the projectile which enter largely into the efficiency of the weapon. In respect to velocity, the experimental 12-pounder of the Royal Gun Factories appears to be very efficient. Col. Owen, in his recent official "Treatise," has given the velocities attained with this piece as ranging between 1550 feet and 1700 feet per second. We believe that even a higher velocity than the latter has since been obtained, but it is not considered desirable to employ such a velocity in the service.

The Government Gun is chambered, the dimensions of the powder-chamber being given in the "Treatise" as 8 inches in length, and 3.6 inches in diameter, the powder charge ranging from 2.75 pounds to 3 pounds. These data may now be departed from, but the total length of the gun probably remains unaltered, namely, 83 inches. The calibre is given as from 3 inches to 3.2 inches and the weight 8 cwt. The question of field guns is now one of great importance, and the impending changes possess much interest.

## MANUFACTURE OF GUNPOWDER WITHOUT WATER.

From "Engineering."

SINCE the general adoption of rifled cannon not a little attention has been given to the improvement of the powder employed for these weapons, the object having been to obtain a powder which would be at once little injurious to the gun, and would have a satisfactory uniform ballistic force. A commission was appointed in Russia in 1871 to study this question. One of its members, Colonel Winer, taking up the idea once suggested by Saint Robert, proposed to

manufacture powder without employing water, and by compressing the materials at a temperature a little higher than that of the fusion of sulphur.

The advantages of powder thus prepared are as follows:—(1) Its hygro-metric property is diminished, and so it is less affected by remaining long in damp places. (2) The manufacture is less expensive, because drying-rooms are dispensed with, and the mixture of the constituents takes place in mixing drums

instead of mills. (3) The danger in manufacture is diminished. As the drying operation takes a long time, large quantities of the material are necessarily accumulated in the drying-rooms whereas, when the powder is prepared directly in the dry state, only small quantities are treated at one time.

Winer was charged to make experiments in this direction in the works at Okhta, and he made the necessary arrangements for the purpose. The latter consisted of a hydraulic press, to which were adapted two hollow plates of copper connected by two pipes of the same metal for the passage of steam. The lower plate was screwed on the plate of the press which was fixed on the piston, and communicated, through a caoutchouc tube, with the steam pipe. The upper plate was fixed and put in communication with the steam pipe by means of an iron pipe. The pulverulent and dry mixture, prepared in the drum, was spread uniformly on the lower copper plates, then the piston was set in motion, and pressure was produced for ten minutes. The disc of powder thus obtained was a perfectly homogeneous mass. The temperature of the steam was about 120 deg. C. With a pressure of 130 atmospheres, measured in the manometers, cakes were got with a density of 1.80 to 1.9; with 30 atmospheres, it was 1.66 to 1.7. These pressures correspond respectively to 114k. and 25.4k. per square centimeter. The cake was reduced to grains by means of crushing cylinders. By means of a sieve the grains were isolated from the rest of the powder; and, lastly, they were discharged into bags.

The comparative experiments made in 1871 with the compressed powder and ordinary powder were not considered satisfactory, and merely gave an impulse to fresh experiments. Only in 1874, after having experimented with a long series of compressed powders of different grain and density, did Winer find one which answered the requirements. This powder had a density of 1.6, a grain of 6 to 8 m., and gave with a charge of 2.250 k. in a long range 4-piece, an initial velocity of 471.5 m in the projectile. The tension of the gas was 1366 atmospheres.

The new powder was next compared with ordinary powder with reference to hygrometricity. In a vessel filled to about a fourth of its height with water were arranged 0.10m. above the surface of the water, two sieves containing, the one 24.6k. of ordinary Okhta large grain powder (density of 1.75 grains 6.3 mm to 10.2 mm) and the other the same weight of Winer powder (density, 1.6: grains, 8.9mm. to 10.2 mm.) The vessel was closed with a lid covered with wax cloth, and left in the open air from August, 1875 to 25th October following. On re-opening it the grains of the ordinary powder were found covered with moisture, black, and so soft that, under pressure with the fingers, they were also slightly coated with moisture, but still quite firm, and they could only be crushed with pretty strong pressure. The former powder contained 6.75 per cent. of moisture, the latter 2.1 per cent. The firing of the long-range 4-piece with these powders, first dry, then moist, gave the following result:—

Species of Powder.	State of Powder.	Charge.	Maximum Initial tension Velocity, of gas.	
			k.	m. atm.
Winer powder	Dry	2.050	438	919
	Moist	2.050	358	778
Ordinary large grain Okhta powder....	Dry	2.350	456.3	1245
	Moist	2.350	323.1	641

The Winer powder lost by its lying in the vessel 11.4 per cent. of initial velocity, and the ordinary Okhta powder 29.2 per cent. The two samples of powder were then subjected to slow drying, at the temperature of 10 deg., from 26th October, 1875, to 5th January, 1876. At the end of this operation the ordinary powder was porous, and rugous in aspect, with efflorescences of saltpetre. The Winer powder, on the other hand, presented nothing abnormal. In firing these two powders so dried gave the following result:—

	Charge.	Velocity.	Tension.
	k.	m.	atm.
Winer powder....	2.050	434.6	1212
Ordinary powder.	1.840	421.5	1166
Ordinary powder.	2.050	443.8	1390
Ordinary powder.	2.250	473.3	1620
Ordinary powder.	2.350	476.6	1660

Thus the Winer powder gave nearly the same velocity as before the humidity test, whilst the ballistic properties of the ordinary powder were sensibly modified.

Colonel Winer further submitted to the humidity test two other samples (or ordinary powder with grains 6.3mm. to 10mm., and 1.75 density; Winer powder with grains 5mm. to 6.3 mm., and 1.6 density) which remained two weeks and a-half enclosed in the vessel. The results of firing were these:—

Species of Powder.	State of Powder.	Charge.	Velocity.		Tension.
			k.	m.	
Winer powder .	Dry	1.95	457.5	1704	
	Moist	1.95	457.8	2200	
Ordinary Okhta powder . . . . .	Dry	2.35	456.3	1245	
	Moist	2.35	417.0	2060	

Thus with the moist Winer powder there was no loss of velocity, while with ordinary powder the velocity was diminished 8.6 per cent. The experiments were conclusive as regards the relative hygrometricity of the two species of powder.

It is easy to account for this difference of property with ordinary manufacture. The water used in moistening disappears in the drying process and leaves in the grain small channels or pores, by which the moisture enters afterwards. Such channels do not exist in the powder manufactured without water.

The new powder is now being experimented with in Russia on a large scale for field guns. Colonel Winer has received an order for 82,000k of it. But hitherto it has not been found possible to prepare a powder of this kind, suitable for 8 inch, 9 inch, or 11 inch cannon and capable of replacing prismatic powder. The above experiments are described in a recent number of the *Journal d' Artillerie Russe*.

## MECHANICAL TRACTION ON TRAMWAYS.\*

By MR. J. L. HADDAN, M.I.C.E.

From "Journal of the Society of Arts."

BEFORE mechanical traction on tramways can be expected to attain the success to which its public convenience entitles it, it is necessary that the question shall be treated as such a radical change in locomotion deserves. The conditions to be imposed upon the machine and the system generally, should be clearly set forth, leaving it to manufacturers to meet them in the most economical manner possible.

The persons whose duty it is to impose these conditions are the following:—The Board of Trade, the civil engineer, the locomotive superintendent, the traffic manager, and the public. Every engineer now accepts that the following theories, although they will work, are anything but commercially sound, and should be abandoned when possible, viz.:—(1) Dead weight is a necessary power (adhesive) on a rising gradient; (2) dead weight is a necessary power (brake) on a falling gradient. If, on the moderate grades of a railway made artificially so as to meet the limit allowed by the above theories these main principles of

railway traction are to be regretted, how much more so would it be the case were we to allow these tenets to influence tramway traction, where the grades are not only steeper but unalterable. The engine manufacturer, therefore, is not the proper person to be entrusted with these grave interests. A rapid street transport service is a public necessity, especially in cities where no underground communication exists, or in districts not served by it. In cities, where the streets are comparatively narrow, acceleration of the through traffic is positively a necessity, being probably the only proper means of relieving pressure; instance London Bridge and its approaches. If all the slow and ponderous wagons which now choke the bridge were, by means, say, of a prohibitive toll, forced to use Southwark Bridge, the general stream of traffic could be so accelerated as never to jam, even if the traffic were two-fold what it is. So far as an irregular traffic is concerned, like the Cassel steam tramway, where the summer service is considerable and the winter service *nil*, steam has decidedly the ad-

\* A paper read before the Society of Arts.

vantage, as, when not in work, the engines cost nothing to keep; but for regular traffic it is only where considerable speed can be permitted, or in situations where greater loads than two horses can manage are required, that steam can compete successfully with horses.

After twelve months' working with twenty-five engines running about 300 trains a day, the following are a few of the leading rules which the experience gained warrants, I think, my laying down with a certain authority, under the five headings before mentioned :

*The Board of Trade.*—(1) The officers of the Board should have certain clearly defined executive powers, so as to insure their recommendations being properly carried out; the power of entire suppression, the only one they now possess, is too severe to be of any use, as it could not be applied severally to the innumerable details, the neglect of which afford such just grounds for public complaint. (2) Each company using steam shall be bound to furnish returns every month of the performance of the engines both active and passive, as also the amount of fuel, oil, &c., used. (3) The steam tramway traffic shall be worked in the opposite direction to the ordinary traffic, if a double line; with a single line this must naturally be the case in one direction. (4) In streets of less than a specified width no steam-car shall stop to take up or set down passengers. (5) On routes where the width of streets is less than a specified number of feet, steam trams shall take up passengers at certain defined points, but may stop where required to set down. (6) In any collision taking place, except at a cross road, the public vehicle shall *prima facie* be held responsible. (7) Any loaded wagon or cart, breaking down on the rails, and thus obstructing the tram-road, shall be deemed responsible, if it is proven that it could have circulated clear of the rails, and was not forced by the narrowness of the street, or other cause, to use the tram space. (8) On approaching all main cross roads used by omnibuses and trams, or where the traffic is considerable, the steam-trams shall slacken speed; and stopping stations, with this view, shall be as often as possible introduced at the arrival side of a

cross road, and never be authorized elsewhere. Where cross traffic may be considerable, and it may not be deemed necessary to establish a station, then police caution notices to the general public shall be conspicuously posted. (9) To prevent undue speed, and insure a regular service, a time-table shall be drawn up, in which each departure and arrival shall be clearly defined, and each engine or car shall bear a distinguishing letter or figure corresponding to its own series of journeys. (10) As a further check on undue speed, the diameter of the driving wheels may be limited to two feet, so as to render quick speed wasteful, and therefore not likely to be encouraged by the management. (11) The fire-box shall be of such capacity as not to require the fire-door to be opened either during the run or at a crowded terminus. (12) Superheating the steam and attenuating it will be provisionally accepted on suburban lines in lieu of condensation, provided the beat of the exhaust be completely silenced, and the chimney be carried up fifteen feet above rail level, when outside passengers are carried. (13) In crowded cities no smoke or steam will be permitted to be visible. (14) Gauge-glass cocks to be so arranged as to be self-closing in the event of a gauge-glass breaking, so that the exit of steam or hot water shall be instantly or automatically arrested. (15) The fender back and front of the engine shall not be deemed suitable unless the clearance above the rails shall always be maintainable at the minimum, notwithstanding wear of brasses and wheels, which is usually allowed for by using a clearance so excessive as to be useless as a protection. (16) No movable points and crossings shall be used with steam traction, unless the needless be lockable, and no movable points of any kind shall be permitted in cases where the road can be laid (as it nearly-always can) with fixed points only. (17) In all cases where the load exceeds the weight of the engine, or when two or more cars are coupled, either a special breaksman shall be obligatory or a continuous brake, worked from the engine, shall be attached to the train. (18) The engine shall be fitted with such apparatus, or appliances, that, should it leave the rails, or otherwise break down, five minutes shall

suffice to clear the road, with the assistance only of the staff of the train. (19) The running front of the engine shall be fitted with projecting reflecting lights, so that not only a disc of light shall be shown, but the whole of the front of the engine, and ten feet of the roadway in advance shall be brilliantly illuminated. (20) No machine shall at any time be left standing on the highway without its proper attendants, whose name or names shall always be conspicuously displayed on their engine. (21) No tram engine shall be allowed to be driven by one man where the variation of pressure shall range more than three atmospheres, or the fire require any attention, or lubrication be necessary, or the boiler require other than self-acting feed during a five-mile run, or any action be necessary which may necessitate the driver diverting his attention from driving. (22) In laying the pavement, the blocks shall be so laid as to define on the road itself the exact overhang of the tram vehicle, so that the public may judge when they are "standing clear."

*Civil Engineers.*—The grooved tram rail has been far too hastily adopted by the profession, seeing that compared with railway traction it will, when dirty, increase the tractive force about fourfold, which amounts on inclines, to almost as much resistance as if asphalté were used. In fact, the only notable advantages a tram rail possesses over a smooth road, say of wood or asphalté, is that it affords direction, without which speed would not be feasible; but as this advantage is not made use of, the value of a tram rail is certainly not at present worth its cost, nor does it warrant the wholesale cutting up of first-rate roads, which experience shows us can never be kept in perfect repair afterwards, owing to the great disparity in hardness existing between the rail and the road material. In America, where roads are bad and carriages few, this difficulty is sufficiently met by using a broad flat tread to the rail, so as to encourage carriages to run on the track itself. I must qualify the above so far as to explain that though a pair of horses can pull more on a tramway rail than on a wood or asphalté pavement, when on the level, a gradient less steep than the mean of most tramways soon brings the two to an equality;

and in some cities where the average grades are heavy, the horse traction on the wood would prove to be the lighter of the two. It is a fact within my own knowledge, that on mounting the incline of the Avenue Josephine in Paris (one in twenty-five), the coachman applies the brake slightly by way of affording relief to the horses in the pull back on their collars, resultant of the effort of the car to recede being thereby eased. In Paris, with a view of diminishing the traction, especially on sharp curves, the groove on the rail is allowed to be as much as  $1\frac{1}{4}$  inches; but do what you will to assimilate a tramway to a railway and obtain similar tractive facility on it, success is impossible, at any rate with a grooved rail. Both on road tramways and on common roads the secret of success lies in abolishing entirely a drawn load, for which a perfectly smooth road is required, in favor of continuous driving, and its antithesis, continuous breaking, a system which does not require too smooth a track, although it will work equally well on either—say, on ice or on sand.

The advocates, therefore, of combined engines and cars are so far traveling in the right direction, but (1) they do not utilize more than sixty per cent. of their weight for adhesive purposes instead of the whole; and (2) the working objections detailed under the heading Locomotive Superintendent will be found insuperable. The undue overhang of the cars produces violent longitudinal oscillations when drawn by steam; these shocks are not only disagreeable, but destroy the stock and road; the remedy hitherto has been the adoption of a long but flexible wheel base; but all the systems tried, without exception, were not at home at the tangents of the curves; for the pair of wheels first on the curve always skewed prematurely those remaining on the straight. Cars for use with steam, if they carry outside passengers, must be greatly stiffened and braced longitudinally, since when the brake is suddenly applied below, it fails momentarily to check the impetus of the passengers on the roof. In Brussels, an articulated train, after the design of M. Dathis, a French engineer, will be tried in a few weeks. The engine is detachable, and the cars (or each articulation)

have only one pair of wheels. The weight of the cars at the joints is supported by girder-like couplings, centered on the axis of each articulation. It is expected to work on curves of twenty feet radius. Considering that in Paris streets one litre of water will thoroughly cleanse a square meter at a cost of about 2d. per annum, it is surprising that tramway companies have not made joint arrangements to wash the streets. The saving in wear and tear to themselves and the general public, let alone the comfort, would amply justify the outlay.

*Locomotive Superintendent.*—(1) For the sake of economy in repairs, no tram-engine should run more than ten, or, say, twelve, hours daily. (2) To ensure due care and economy in the driving, every driver must have his own engine, and no one else be suffered to touch it. (3) During the day it was found necessary to sweep the tubes, and also to inspect and clean the machinery, as it could not be properly done, either morning or evening, in the dark. (4) Reliefs were performed by changing the engine bodily on passing the depot, and therefore without inconveniencing the passengers; when, however, a car broke down, every one had to change carriages, and the conductors were in despair as to who had paid and who had not. (5) Owing to the grease and dirt attendant on a running shed, it was found impossible to keep the cab in as decent order as the corresponding car; it was, for this and other reasons, abandoned in favor of an open iron weather shelter. I am decidedly of opinion that a detached engine is a *sine qua non*. (6) Rigid underframes should be condemned, as also crank angles, owing to the cross bending strains incident on an irregular road; coupling rods, because of the curves; and eccentrics and open axle boxes, by reason of the mud. (7) Volute springs have not been found to answer, the old C spring is far superior in distributing the shock. (8) Free play to the horizontal boiler, both laterally as well as longitudinally, is imperative, as, if fixed, it is so affected by the curves that the tube plates converge and tight tubes are an impossibility. (9) The brake should never be applied on the wheels, but on false tires readily renewable. They

should be applied on both sides of the engine, and should not be arranged so as to strain the coupling rods, by either forcing the wheels together or driving them apart, nor should counter-balanced wheels be used. These remarks apply also to the cars. (10) The joint surfaces should be nearly double what is usual in a locomotive, owing to the constant use of the reversing lever and endless stoppages, which, in other ways, also tax the engine severely. (11) The steam chests should, as in Mr. Brown's Winterthur engine, be upside down, so as to drain the cylinders, and thus avoid the use of pet cocks. All the wearing surfaces should be excessive, and liners used wherever possible. (12) The machine must be powerful enough to push before it to the nearest siding any train which may break down, a further nut to crack for the combined car. (13) Side fire-doors are undesirable; they have been found to raise the tube plates by admitting cold air currents.

*Management.*—Steam traffic has to be managed on an entirely different basis to horses or railways. Steam traction in Paris now pays nine per cent., while the tramways and omnibuses are earning little if any dividend, although horse keep is cheap and fuel is dear. On making the usual false comparison, viz., per mile only, instead of per mile in conjunction with the weight carried (receipts), which is the only fair plan, since it represents work done, we find the cost in favor of horses. But when we reduce the competitors to the test of work done, as in column A, the result is greatly in favor of steam. See table:

(See Table on following page.)

The fares of the car of forty-eight passengers, when full, represented 3s. per mile on the line in question; but on certain days, owing to constant mutations, the earnings have been known to amount to 5s. 9d. per mile. The useless number of journeys run by the horses, and the value of the consequent extra dead weights, may be fully realized when the receipts only averaged 1s. 2½d. The cost of steam traction, with two full cars instead of one, is only increased ¾d. per mile for fuel and oil, which brings the cost per mile up to 8.18d. (in France), or less than horse traction on a far easier line with only one car. In

PARIS.—TABLE GIVING COMPARISONS BETWEEN HORSE AND STEAM TRACTION.

Classification.	Nature of road.	Working expenses per mile run.	Receipts per mile run.	Receipts per seat, averaging 0.45d. per mile.	A.
					Working expenses per mile. Work done equal in all three cases.
Steam.....	Steep.....	7.43	s. d. 2 8	d. 0.66	d. 7.43
Horse line.....	Easy.....	6.40	1 10	0.46	8.49 }
Horse line.....	Steep.....	8.56	1 2½	0.30	11.37 } Average 9.93

Paris, on easy lines, ten horses work one car per day, and do about twelve miles per diem; but with so large a car this number of horses would not suffice, if managers (with the view of showing a low cost per kilometer) did not relieve their horses, by giving them on an average less than half loads; that is to say run double the number of trips necessary. I consider that ten horses can readily work an omnibus with its load of twenty-six passengers, but ten horses cannot readily work a tram (grades, &c., being equal) with a load of more than thirty-five passengers. A six-ton tram engine can work a load of 100 passengers.

*Roulement.*—The system adopted in Paris of *roulement* is devised for obtaining uniform and comparative statistical results, no matter how irregular the service. Thus by the system of *roulement*, at the end of the month each engine and driver will have performed precisely the same mileage, he should also have expended the same fuel and oil; and the wear and tear of the machines, if carefully driven, should be precisely the same. All the conductors' receipts should also be of almost equal amount, and thus by comparison systematic dishonesty or neglect can be instantly detected. The bell-punch and uniform fares is the best control I have yet seen; but even that system requires public assistance to make it work satisfactorily.

*Public.*—All the public ask for are, quick through traffic, low fares, and a strictly-observed unvarying time table. Correspondence also is a public necessity, but too little understood in this country to be said to be a demand. By the establishment of suitable shelters, to the installation of which the public have as much right as cabmen, and of a miniature clearing house for settling accounts, a traveler could take a through ticket

from one end of town to the other by the first public conveyance available, and change vehicles *en route*, if by so doing his journey might be more rapidly or more conveniently performed.

Colonel Beaumont, M.P., has pointed out that a steam tram-engine is obliged, both in steam capacity and in weight, to be used of the maximum type which starting on the stiffest gradient exacts; and that, consequently, we daily see a twenty horse-power engine called upon to do duty which three horses could perform, and which, on a level, the engine-driver and stoker could almost undertake unaided. This discrepancy and waste of power Colonel Beaumont attributes to the fuel being used locomotively; and, certainly, the mere horse-power required, if generated in a fixed engine, could be procured with about eighty per cent. less fuel. Colonel Beaumont, therefore, compresses air, and converts it into horse-power at about one-fifth the cost of steam; but as, in expanding the air again, he loses about seventy per cent. of the power stored, the actual gain is not more than ten per cent. Lamme's American fireless engine, besides the fatal inconvenience from loss by radiation, which renders every stoppage killing, is not economical in storing the power. Todd of Leith, seems to treat the question of exhaust in a very masterly manner, but I have no personal experience of his invention. Rowan, of Copenhagen, is the father of the combined car type; he has lately, however, gone in for a detached engine, the merits of which are kept secret. He claims for the former all the well-known advantages on a bad road of the bogie—of getting on the line easily again, also by means of steering the bogie—a strong break power, saving of dead weight, and a fan blast which does duty as an air-con-

denser. Brown, of Winterthur, whose latest engine I had the opportunity of examining in Paris, has in it produced a superior article. The machinery is raised five feet above the rail level, and the driving power is transmitted by vertical levers and coupling and connecting rods. The levers, being always in opposite directions, no counter weights are required. Hughes, of Loughborough, takes a prominent place, because he has shown he can do good work at a moderate figure, while his engines have been running fifteen hours daily, a most severe test. The following statistics of the Vale of Clyde tramways show that he worked at 5.61d. per mile, coke costing 24s. per ton, as against 48s. in Paris, and his engine requiring one man in lieu of two. The coke consumption was eight pounds per mile.

## EXPENSES FOR SIX DAYS, OR 1800 MILES.

	£	s.	d.
Eight drivers, at £1 7s.....	10	16	0
“ overtime fifteen hours.....	0	8	4
Two cleaners, at £1 2s. 6d. ....	2	5	0
Waterman and coke carrier.....	1	5	0
Lamp cleaner (boy).....	0	10	0
Coke, 6½ tons, at £1 4s.....	7	16	0
Oil, suet and waste.....	2	0	0
Water, 63,660 gallons, at 4d.....	1	1	3
Salaries of manager, timekeeper, and office expenses.....	5	10	6

£31 12 1

## REPAIRS.

Leading fitter.....	1	12	0
Three fitters, at 30s.....	4	10	0
Smith, job work.....	0	10	0
Carpenter.....	0	5	0
Materials, 12s. per engine.....	3	0	0

£9 17 0

Running expenses.....	31	12	1
Repairs.....	9	17	0
Interest and sinking fund, say 20 per cent., on £5000.....	0	13	1

£42 2 2

(£42 2s. 1d. ÷ 1800=5.61d.)

Messrs. Merryweather, the well-known fire-engine makers, have had more engines running than any other maker, having turned out about fifty. The earlier makes, however, were far too small, and required such constant attention as to have been provocative of many collisions, owing to the driver having multifarious duties to perform, which interfered with a sharp look-out. In Paris no condensing or speed-checking

apparatus was required by the authorities, so they were not supplied. Their Cassell engines were far superior, and have, it is said, been eminently successful. Messrs. Fox, Walker & Co., through being last in the field, have profited by all the experience gained by fifteen months' constant work in Paris. They are supplying the French Traction Companies of Paris and Rouen, and their engines, for workmanship, economical working, and skillfully-met conditions leave little to be desired. The object of this paper is to stimulate discussion on the whole subject.

Mr. J. Scott Russell, F.R.S., said they must all be much obliged to Mr. Haddan for the information he had given from his practical experience, which was especially valuable at the present moment. He had seen the engines of Mr. Hughes in Scotland, and Messrs. Merryweather's elsewhere, and had always considered that there was great promise in them; and he had no doubt that if the mechanical engineers of this country really set about the task, they would be able to create the very engines that were wanted in a perfectly satisfactory manner. He knew well what the difficulties were from his own experience of engines, for he had had the same class of difficulties to grapple with. It was quite correct to say that much larger bearing surfaces were required in such engines than in locomotives, and many adjustments which were not there called for. He also agreed with Mr. Haddan as to the extreme weakness of crank axles generally, but, of course, with a little experience, they would learn how to make them strong enough. Still they would not be wise things to use where concussions were constantly taking place in every possible direction. The great question appeared to him to be this, was the separate engine or the engine combined with the carriage the better of the two? He thought there were circumstances as to exceptional gradients and other things, which in one instance would go in favor of the combined engine, and in different circumstances would go in favor of the detached. At present his impression was that a steam locomotive engine, both for economy and management of stock generally, should be a separate carriage, however

it might be made to appear outside as though it were a part of the other carriage; and that on the other hand, where you determined on the combined system, you ought to abandon steam and take condensed air or some such motor as the propelling power. His opinion, therefore, was against applying the steam-engine in the car itself, and in favor of using it separately, and in favor also, in certain circumstances, where you could conveniently do it, of having stationary reservoirs of power at which you could fill the reservoir of the carriage with condensed air and use it as an economical and convenient propelling power. It was obvious that a large carriage with a couple of boilers in it was, to say the least, not very nice company to travel in. The great thing to be done with the detached engine was to make it more durable, and the only way in which this could be done was to more perfectly detach the propelling power from the propelling axle, so that all the mechanism of the engine should be relieved of the shocks upon the wheel. In no engines he had yet seen had that been perfectly done. This paper would contribute materially, to assist engineers in meeting the various difficulties which had been quoted; and he hoped the mechanical engineers of England would now devote their attention to this subject, and that the public generally would thoroughly take up the tramway question. It was the great supplement to the railway question, and his opinion was that, instead of extending railways by small branches all over the country, it was now desirable that from every railway station should proceed, in all directions, a well-organized system of tramways. He would advise engineers to keep their locomotives out of Cheapside for the present, and rather to apply them in suburbs, where they would form a great public convenience to many, and would inconvenience but very few.

Mr. Matthison said, that the profession had had but little to do with the grooved rail, which had been forced upon them by the authorities. In the United States, where they had more scope, they did not use them. In the interest of people who rode in carriages, there was no doubt the grooved rail was good, but for the tramway company the flat

rail was much preferable, and when the question of steam-engines came up it was of still more importance, because much of the difficulties of the steam-car had arisen from badly laid rails, which at the best had been made only for horse-cars. Discussion as to steam-cars was useless until the best form of tramway had been decided upon. The point mentioned by Mr. Scott Russell of detaching the mechanism of the engine from the jolting of the road had been very successfully accomplished by Messrs. Kitson, of Leeds. There the action of the steam-engine was applied to a central axle, from which the power was taken to the wheels, thus saving the gear from the jolts of the carriage.

Mr. Kincaid said, Mr. Haddan had laid down certain hard-and-fast rules, which it would be difficult for civil engineers to follow in practice, because there was hardly a case which came under their notice in which they did not find very different circumstances. For instance, the grooved rail was an absolute necessity in crowded towns where there was much carriage traffic, but it was not so in America, where this kind of traffic was comparatively small. No doubt the grooved rail with a fillet gave much more work to the engine than one without, and in many of the future lines, to which Mr. Scott Russell had alluded, it need not be insisted on, and a modification of the ordinary railroad might be adopted on which the traffic could be carried much more easily. He did not quite follow the table of receipts and expenditure, and it seemed to him that the working expenses were put very low—much lower than he had seen worked out anywhere else. As a rule the expenses were a great deal more than fifty per cent. of the receipts, and he was not aware that the Paris tramways were worked at so much smaller a percentage. The only experience they had had of the control of the Board of Trade in this matter had been in Glasgow, and from the report just issued by General Hutchinson he came to the conclusion that the Board had well considered the matter, and were working out the general ideas of the committee alluded to by the chairman.

Mr. J. Stables had had some little to

do with the construction of the steam-engine patented by Mr. Brunton for the combined car used on the Wantage branch line, which answered very well. The requirements of the committee, to which reference had been made, were very difficult to meet. They required the car to stop immediately, and not to exceed a certain rate per mile, and several patents had been taken out to effect this latter point mechanically. Mr. Stables said it was quite plain the report of the committee, if adopted, would place some difficulties in the way of construction, and he believed that this was the reason that the matter had not been more attended to by mechanical engineers, because they felt sure that some time must elapse before the engines would be required. The public required a car which made no noise or smoke, and which could be stopped at any moment, to run upon a rail level with the street, and not to interfere in any way with carriage wheels. In New York the rails stood above the surface, and were almost as strong as those of a railway, and engineers had no difficulty in making engines which would run well upon them. The present rails required a very light engine to run upon them; thus it was found that the resistance was much greater than was anticipated, and therefore the cylinder area had to be made larger and the machines heavier. The cylinders in Messrs. Fox, Walker & Co.'s engines were placed high up above the boiler, but unless they were in the center of the engine there would be great oscillation, especially if there were two cylinders. He would suggest the cylinder ought to be in the line of pull and thrust, so as not to interfere with the springs. Again, the axles and bearings should be made like the old mail-coach axles, with leather washers and oil boxes, and every part should be well covered and protected from dust, which was the great cause of repairs being needed.

Mr. Rowan (Copenhagen) said, it was quite true that the late Mr. Grantham made a combined car before he did, though he had previously taken out a patent. He might venture to give the result of his experience, because it was gathered from different sources abroad, and he had no interest or prejudice in

favor of one maker more than another; he simply wished to get the best engine and the best system. Although he was not entitled in any way to be called the father of the combined car system, he was quite prepared to take the responsibility of it. The trials he had made since he had ridden on Mr. Grantham's had convinced him more and more that the combined car would carry the day over the detached engine. Without entering into the question of whether compressed air or steam was the best, he thought that whatever engine was the best for the one would be decidedly the best for the other. There was a new field now open to the mechanical engineer, viz., to make a light engine. No one had tried in connection with railways to make a light locomotive, because there you must have weight to drive the engine, but in the combined car, if you could make an engine sufficiently powerful which weighed only 100 lbs., you could take it up any gradient, because half the weight of the load would always be on the driving wheel. He believed that if mechanical engineers had their attention directed to this point they could make engines strong and solid, and yet infinitely lighter than  $5\frac{1}{2}$  or 6 tons. Mr. Haddan laid great stress on the point that the engine and car combined would necessitate the engine going to the repairing shop and the car with it, but that was by no means the case with a car of the type he had been experimenting with, and he had seen the results of over a thousand miles run, under the direction of the Prussian Government. The engine could be detached from the car in two or three minutes, and any engine could be used with any car, although you got the full advantage of using the weight of the load to go up hills; and he laid great stress on that fact, because if you wanted to make cheap new lines to serve the railroads, you must expect to encounter sharp curves and steep gradients. He believed Messrs. Kitson's engine was the best which had yet been devised, being much lighter, but with great power, having 28-inch cylinders, with a 15-inch stroke. They also had the advantage of being entirely boxed in from mud and dirt, and every part was under the driver's eye and control, and he could clean up

while waiting and stopping. Still, he hoped before long, they would see an improvement even upon that.

The Chairman, in proposing a vote of thanks to Mr. Haddan, said he did not think an outside cylinder would get over the difficulty of crank axles, because if you connected the leading and driving wheels it must be by means of a crank axle, so that, whether the cylinders were inside or outside, you must have a crank axle, unless you adopted the system of Messrs. Kitson. Mr. Scott Russell had endorsed what he believed was the correct principle, in laying down that if you had steam you must have a separate engine, because the inconveniences of steam were such that you could not have a steam-engine side by side with the passengers. His name had been mentioned in the paper in connection with an air-engine, and one of the advantages of that system was that it got over the difficulty, inherent in steam, of combining the engine and car together. He might express a hope that, on some future occasion, he might have an opportunity of reading a paper, and explaining what he had done in that direction; and he believed there was

every probability of such an engine occupying, with success, the field alluded to by Mr. Scott Russell. It was extremely desirable to have some means by which you could limit the speed on tramways, but when the committee came to consider the great difficulties that were in the way of providing any mechanical and self-acting regulator, they dismissed it as being impracticable. It appeared to him that what mechanical engineers had to attend to was the absolute production of an engine which would fulfill the requirements laid down by the committee, and which would not run only two or three days together when committees and engineers came to see it, but should bear the test of continual working, and should have earned its money when it came to the end of its six months, and paid its working expenses. When that was done, it would be a great stride towards the extension of the power of locomotion in this country, namely, the extension of tramways. Railways formed the main arteries of communication, but it remained for tramways to complete the communication with villages and other places which could not otherwise be reached.

## STEEL PLATES.

From "Engineering."

It is universally allowed that steel plates made from a metal in a state of fusion, cast into an ingot and then hammered and rolled, are much more likely to be mechanically homogeneous than iron plates made up of a number of pieces welded together by hammering and rolling. We use the term homogeneous in the sense in which it is usually employed when speaking of the difference of structure in steel and wrought iron. To the soundness or homogeneity of steel plates is due the freedom from lamination and blisters, the more equal tenacity and ductility lengthwise and crosswise, their bearing cold flanging and bending so well in all directions, their standing being solid drawn like copper or lead, and the severe cold punch test they are able to bear, compared

with best Yorkshire plates. Homogeneity, however, does not mean absolute uniformity of structure. In a homogeneous steel plate, we may find different degrees of ductility and hardness, by which differences in structure are implied. The homogeneity of steel plates is almost universally regarded as an unconditional advantage. With this general opinion we do not, however, entirely agree, and it appears to us that its unchallenged acceptance has frequently led to many of the cases of disappointment occasioned by the failure of steel plates, and their being now considered untrustworthy by many of those who have tried to use them.

A sound strip of very inferior and brittle iron plate, having the tenacity of say, 21 tons and 18 tons respectively

along and across the fibre, and a ductility of 3.5 and 1.5 per cent. respectively in 8 inches may be broken by a single blow with a hammer. A sound strip of steel plate of the same dimensions having a tenacity of 36 tons and an elongation of 10 per cent., will resist a much severer blow, or a number of equally severe blows oft repeated. Should, however, the strips have a very slight fracture at the part affected by the blows, either at the sides or edges, such for instance as might be caused by the careless use of shears in bad order, the conditions of comparative resistance may be completely altered. A number of light blows may now break the steel strip, which will not injure the iron plate. By being in a state of tension the tendency of the steel strip to break before the other will be further increased. The flaw or incipient fracture, which will scarcely affect the strength of the iron, may seriously affect the strength of the steel. By a slight accident of finish, what would naturally be considered the tougher and stronger, may actually become the more brittle and less trustworthy material. This appears to be the explanation of what has frequently taken place and been ascribed to capriciousness on the part of the material. The hammering of a hard plate with a roughly-dressed or undressed edge may cause an incipient fracture in a plate. When this plate is placed in the shell of a boiler tested to 10 tons or 12 tons per square inch, or in the firebox of a locomotive, and exposed to varying strains due to changes in the pressure and temperature, these incipient fractures pass, sometimes suddenly, into the body of the plate, often avoiding the rivet holes in what has been called a mysterious manner. This apparent caprice is doubtless due in a great measure to the homogeneousness of the material.

When the plate has not suffered from tempering, the resistance of the material is practically uniform and the fracture tends to pass in a straight line, being readily extended by jarring or vibrations. In an iron plate, owing to the want of homogeneity, and the unequal resistance at different points of the material, the fracture often takes such a direction that it is not affected by jarring even when the plate is strained,

and allows the stress to spring the plate, without tending to increase the fracture, which is tantamount to having the ductility of the material increased indefinitely. This is especially the case where the iron plate is stretched in the direction of its fibre.

The possible advantage of a want of homogeneity may be roughly illustrated by the well known expedient of arresting the progress of a fracture in an iron, by drilling a hole at the end of the fracture and inserting a rivet. The want of homogeneity tends to arrest the progress of a fracture along or across an iron plate, as lamination arrests the progress through the whole thickness of a plate of a fracture on one side, the starting of which in the first instance may have been indirectly due to the presence of the lamination. Apart from the advantage a stranded wire rope possesses for coiling and uncoiling compared with a solid rod of similar thickness, there is an element of strength imparted by the mere fact that the severing of one strand does not impair the efficiency of the remainder, and this is very important in many situations and purposes to which copper, steel, and iron ropes are applied.

Where there is a tendency for the stresses to gradually work open the material, as at the root of a flange in the furnace tube of a Cornish boiler, and where there is no injurious chemical action of the water, a tough steel flange will resist fracturing longer than an iron one, but when the fracture has once been started, the structure of the steel tends to make it go much more quickly.

We have in the above inquiry suggested the quality, viz., *ductility*, that is wanted in order to counteract that which tends to make the homogeneity of steel a positive drawback, causing the material to give way without warning. In the few works where steel plates, having about the same ductility as ordinary iron plates, are skillfully treated, such plates can be successfully used, But for the general run of boiler-makers and shipbuilders, a greater ductility is necessary for the successful use of steel than is required for iron plates.

Accurate knowledge on this branch of the strength of materials is still wanting. It is, however, probable that the

stronger and less ductile the steel, the greater will be its resistance to the starting of a fracture, but when a fracture has once been started the greater the ductility, and consequently the less the tensile strength, the more suitable the material for resisting the further progress of the fracture, especially where there are jarring strains or strains of varying intensity, and where the material is in a state of tension. In all cases where the strain is unequally distributed, as at the overlap of plates in tension, the greater the ductility the more uniformly will it allow the strain to be distributed over the section.

The soundness of steel plates is not quite so general as is often taken for granted. The blow-holes or honey-combing commonly found in the ingots are certainly not always removed by the subsequent hammering and rolling of the material. Some steel manufacturers affirm that the metal separated by the bubbles of air or gas cannot be welded together by the work done upon the material in the ordinary process of making it into plates. Others maintain that the metal round the holes in the body of the casting, which is clean, does become welded together, whilst the metal round the blow-holes which has a film of oxide on it, can never be welded by any amount of subsequent hammering and rolling. Where the metal round these blow-holes does not get welded together the holes become flattened out in hammering and drawn out in rolling. They sometimes appear as streaks or lines on the surface of the plates, and these lines cannot, in many cases, be regarded otherwise than as incipient fractures the spreading of which, the structure of the rest of the material, especially if at all hard, is so badly designed to resist. We have here another reason for getting as ductile a steel as possible.

It, however, unfortunately happens that the softer and more ductile the material, the more spongy and honey-combed it is likely to be. We have then until lately been in this dilemma, that the greater the ductility we succeeded in obtaining, the greater was the risk we ran of having plates unsound, thus incurring the very fault we require the ductility to withstand. One way of getting out of this difficulty was shown

by Mr. Bessemer long ago, this plan being to compress the steel whilst in a state of fusion. Subsequently this plan of compressing fluid steel was carried out by Messrs. Révollier, Biétreix & Co., in France, and later still at the Neuberg Steel Works, in Austria, while in this country Sir Joseph Whitworth has carried out this mode of treatment for years and has developed it most successfully for certain purposes. Considering the nature of the plant required, however, there appears to be little chance of this system of working being adopted for the commercial production of blooms for the manufacture of steel plates, and hence recourse must be had to other modes of obtaining soundness. That a vast advance in this direction has been made in the past two or three years no one who has watched the progress of our steel manufacture can possibly doubt, the employment of ferro-manganese having been attended with most important results as regards the production of mild steels. There is also no doubt whatever that our steel manufacturers are fully alive to the importance of ductility in the plates they produce, and the leading firms are and have been for some time past turning out material which is very satisfactory in this respect. At the same time this material requires proper treatment, and it is with a view of promoting this treatment that we have in the foregoing article dwelt upon the influence which the homogeneity of steel plates appears to us to exert on the power of such plates to resist incipient fractures.

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At a recent meeting of the French Academy of Sciences a paper was read giving an account of the working of a very successful ventilating apparatus lately fitted on board the French transport *Annamite*, one of four large vessels built for conveying troops to and from Cochin China. The ventilation of the ship is effected by utilizing the heat escaping up the funnels when the vessel is under steam; or by lighting small fires for the purpose when the transport is lying at anchor; and especial attention has been given to providing for the ventilation of a sick bay established in the center of the vessel, and also of the deck on which the men sleep.

## THE WORK OF THE EARLY STONEMASON.

From "The Builder."

PROGRESSIVE development of the art of the mason forms the subject of a special chapter in the history of architecture. It is a chapter of no small importance; as its study will be found to extend to the earliest dates of human history, if not into pre-historic times. The facts on which any theory must be constructed are durable realities. And the special value of the investigation consists, not only in the fact that it endeavors to fill up a gap in the history of architecture, both as a science and as an art; but that it further tends to link architectural with ethnological progress, and to exhibit those steps in the history of various races which have been parallel in the order of national development, although not in actual time.

The subject has especial interest, as tending to throw some light on the noble pre-historic relics of our own island, as to which there is so entire a break with regard to any traditions of their origin. We do not forget the efforts that have been made to bring down this origin to the recent date of the Roman occupation of Britain. Without, at the moment, insisting on the weighty arguments opposed to this view, for some of which we may refer to our own columns, we think that it cannot be denied that to trace the development of the art of the stone-cutter is a method of research which cannot fail to throw some light on the question.

Masonry, as the term is now ordinarily employed, may be taken implicitly to include the idea of stone-cutting, as well as that of the use of cement, or some artificial method of joining stones solidly together into a mass. But the definition given in the last edition of Johnson's Dictionary is "craft or performance of a mason." And a mason is simply defined as "a builder in stone." These terms cannot be bettered; for they include not only the most finished effort of a perfected art, but the rudest steps of its commencement. Such was the work to which we recently called attention at Tiryns, where vast unshapen stones are piled and fitted into walls, "with only

occasional, and apparently later, marks of the tool."

It has, perhaps, escaped attention hitherto, that between the first stage of Cyclopean, or primitive stonework, and the second stage,—in which, while the idea of the course of masonry is undeveloped, the sides of the several stones have been reduced to plane, though rarely vertical joints,—has intervened a step in human progress which is not due directly to the mason. We are apt to look at the succession in question as if it were the simple development of masonic skill. But we have no reason for assuming that the builder of Tiryns was unaware that it would have been better to dress his joints than to pile stone upon stone, fitted as best he could. Something was required beyond the wish to make the strongest wall possible. That something was a tool that would cut stone.

As to this, it is perhaps safer to put our views in a tentative form than to attempt to speak with a preciseness as yet unjustified. What was the first tool of the stone-cutter? How far was it possible to cut stone with stone tools; to dress joints by the use of axes of obsidian, jade, or any hard stone? The subject is worth a little experimental research. Supposing it to be shown that such a commencement of stone-cutting was a possible step in the art of the mason, we think that a certain distinction may by this means possibly be pointed out in the examination of ancient masonry. For while a stone axe might, we apprehend, occasionally be used, especially in the case of tufa, and of not a few descriptions of less compact rock, we are not prepared to admit the applicability of a chisel made of stone. If this be so, we shall find in the transition from axe-dressed to chisel-dressed stone a note of time which indicates at what period in his progress the mason was first indebted to the contemporary skill of other artisans for metal tools.

This brings us to another question, of no small importance, if thoroughly solved. To what extent was it possible

to cut stone with a chisel before the introduction of iron? We are aware from literary testimony that the manufacture of iron dates much later than that of bronze. Not that the subject has been exhaustively treated; but still iron, when it first came into use, appears to have been the rarer and more highly valued metal. In Homeric times (when-ever they date) bronze or brass was used not only for defensive, but for offensive arms. The earliest date to which we can with certainty carry back the proof of the use of iron is 5,400 years ago. In the Pyramid of Souphis (or Cheops) iron has been found in such a position as to leave no doubt that it had been in the possession of the builders of the pyramid, under the fourth dynasty of Memphite kings of Egypt. This significant discovery may perhaps throw light on another question of extreme importance as regards the history of masonry. That is,—how were the hieroglyphics cut? We shall be indebted to those learned men who are doing so much to unveil the written mysteries of Egyptian history for any definite statement of the date of the most ancient incised hieroglyphics; and also, as to the fact whether any appreciable differences in the style or mode of cutting is to be detected, and referred to known dates. The general impression produced by a study of the inscribed statues and *stelae* at the Turin Museum, at the British Museum, and elsewhere, is, that as far back as Egyptian relics exist, the hieroglyphics were cut in basalt, green-stone, granite, or other hard stones, with a depth and a precision which are those of the gem-cutter rather than of the stone-cutter. As iron was known in the time of the fourth dynasty, steel might have been also known; or the use of iron of meteoric origin, or of extreme purity, may have given to the early inscribers the means of effecting their work. On the other hand, there is the possibility that some kind of drill was used for the inscriptions; and if corundum powder was employed, a soft iron or copper drill might have been sufficient for the purpose of the workman. Adamantine corundum, an excessively hard spar, occurs among the granite and mica schists of Egypt. Granular corundum, or emery powder is found in Greece, and may

very probably have been known to the early Egyptian artists. At all events, this part of the subject will repay research. At present we will only attempt to lay down the principle, that the mode of cutting stone that was employed at any particular period affords an index to the knowledge and use of metal tools possessed by the masons of that time and country.

In Mycenae we have instances of the cutting of stones of the magnificent dimensions of nearly thirty feet by eighteen feet by four feet. At Avebury we have stones, presumably once cut, of almost equal size. In the Great Pyramid we have examples of enormous stones cut so that the joints are impenetrable to a knife-blade. In the walls of the Haram or Temple enclosure of Jerusalem we have stones of the same giant family, some of which are not older than the time of Herod the Great, or the commencement of the Christian era. We have thus a range of certainly 3,500 years, during which the masons of Greece, of Egypt, of Syria, and possibly those of Wiltshire, cut, dressed, and set enormous stones. To how much earlier a date we may hereafter be able to push back the commencement of the art of stonecutting, which we think may be fairly associated with the presence of polygonal cut stones in a wall, we cannot attempt even to guess; but we have, at all events, something like a means of measuring the relative advance of various tribes or nations by the comparison of their works. Whether the builder of the Great Pyramid wrought 1,000 or more years before or after the builder of the walls of Tiryns, the former was certainly a much more educated and experienced mason than the latter. So again, by comparison of their works, we should conclude that the masons who built Stonehenge and Avebury were much earlier, dating by their professional knowledge, than those who built the Pyramid. Civilization, we know, has often been narrowly localised. A high state of industrial perfection in one country may co-exist with a low condition in another at no very remote distance. If this were not the case we should have something approaching to the nature of proof that Stonehenge is older than the Great Pyramid. We are

unaware of any good data for fixing the earliest possible period of the erection of the English megalithic temples, though reasons have been adduced in this journal for the opinion that marked geological changes have affected this part of Europe since those noble structures were completed.

Another very ancient evidence of the art of the stone-cutter is to be found in excavations of rock. Of these the examples in Egypt, in Eastern Syria, in Western India, and elsewhere, are not unfamiliar to the architect. Very generally they give signs of being of much later date than the megalithic buildings of which we have been speaking. A trabeate form of architecture has been imitated, in numerous instances, by men who wrought in the living rock. But there are two groups of stonework *in situ* as to which we are as yet only in course of receiving definite information. These are the military rock defences of Palestine, and the rock-cut tombs which abound in the Holy Land. The old sites of the Jewish cities are for the most part covered with mounds of rubbish, in which it is utterly vain to expect such surprising relics to be hidden as have rewarded the explorers of Mesopotamia. But very often the modern towns which bear the names, and no doubt stand on the sites, of Biblical and pre-Biblical cities, are surrounded by a scarp of rock artificially cut. "The most wonderful of these scarps," writes Lieutenant Conder, R.E., in the Quarterly Statement of the Palestine Exploration Fund for January, 1878, "is that at the south-west corner of Jerusalem, where a carefully-worked wall of rock, fifty feet high, is traced for over 150 yards. Similar scarps, on a smaller scale, are not uncommon throughout the country." The account given in the Book of Samuel, of the capture of Jerusalem by David, 2,900 years ago, gives reason for the belief that the rock scarp was at that time in existence, even if it may have been carried to a greater depth later; as to which, however, there is no evidence.

The same explorer calls attention to another work of the stone-cutter in the same country; namely, the excavation of rock-cut reservoirs and cisterns. "Bell-mouthed cisterns occur so constantly near, and in connection with, Jewish

tombs, that it seems natural to ascribe them to Jewish workmen, though they have no marks of date which will fix them so early." It is, however, evident that works of this nature must have been co-eval with the settlement of many parts of the district bordering on the Mediterranean. Those tribes which inhabited watered plains, or dwelt on pervious soils, in which they might find springs, or dig wells, had no need of the services of the quarrymen and the mason in combination. But where the soil is rocky and impervious to water, where the rainfall is unequally distributed throughout the year, and where the temperature renders a certain abundance of water a necessity of life, no permanent habitation of a country can be effected without the construction of cisterns.

Of like nature to the Syrian cisterns are the granaries or treasuries that are sunk in the soft, dry rock so prevalent along the Eastern versant of the Apennines. In the neighborhood of Foggia, where rich crops of corn are secured in the summer months, the ground is, in some places, honeycombed with bell-shaped or conical excavations, in which corn is stored sometimes for many years. The form of those granaries so closely resembles that of the Etruscan tombs, in which the arch is anticipated by the progressive over-setting of course above course of small bedded and squared masonry,—set, in some tombs that we have opened, without mortar,—that it seems proper to associate the excavating with the building stone-cutters of *Magna Grecia*, and probably of other countries.

With regard to tombs, the explorations of Lieutenant Conder throw light on a very important mark of relative antiquity. Near to every modern village or ancient site of a town in Palestine, usually on some opposite hill, are to be found rock-cut tombs. They are hardly ever found within the ruins. They may be divided into three classes. Of these, the first bear the name of *kokim* or oven-like tombs. They are formed by cutting small parallel tunnels, each of the dimensions proper to contain a human body, from the sides of a rectangular chamber. The *kokim* vary in number from one or two up to eighteen or twenty; and in size from the length of three feet to that of seven feet. There is no system of

orientation. The entrance-door to the chamber is in the face of the cliff, and the chamber itself is excavated in accordance with the lie of the rock. The chamber may probably be regarded as the original provision for a family tomb; fresh *kokim* being cut from time to time, as wanted, of dimensions not larger than requisite for the sepulture of the individual for whom it was cut.

The proof that this form of tomb is the oldest in the country is definite. The second class of tombs is that containing *loculi*, or side receptacles, parallel with the walls of the chamber, instead of being at right angles to it as in the former class of tombs. The *loculus* arrangement is still adopted in mausoleums in Italy, as for instance, in the Superga, near Turin, where the members of the Royal family of Savoy are laid to rest in parallel niches, something like the berths in a vessel, the faces of which are walled up on the interment being made. That these tombs in Palestine are of later date than the *kokim* is shown by the fact that there are instances in which an outer chamber, containing the former kind of receptacles, leads to an inner chamber,—pierced further in the rock,—containing *loculi*. But no instance has been found in which the order is reversed.

Of the anterior limit of the date of the *kokim* tombs it can only be suggested that it may probably have been as early as the inhabitation of Palestine by a burying, as contrasted with a burning, race. That they were used by the Jews is shown by the description given in the Talmud, and by the occurrence of Hebrew inscriptions, and of a representation of the sacred candelabrum in certain cases. To others a traditional veneration is attached. But the substitution (in part or in whole) of the second for the first method of construction is shown to be older than the Herodian time by the references made by each of the Evangelists to the rolling stone with which the mouth of the tomb in the garden was closed. This arrangement is said by Lieut. Conder to occur almost invariably in the *loculus*, but not in the *kokim* tomb. An inclined groove is cut before the entrance to the chamber, and a cylindrical stone, like a mill-stone, is placed in the groove. To enter the

tomb it is necessary not only to roll the stone up the slope, but to wedge it up, as it would otherwise descend with its own weight, and completely close the entrance.

The tombs belonging to the second group are more ornamented than those of the earlier system. Some of them have facades covered with a rude kind of imitation of Classic mouldings. "There is generally a portico, with a frieze above, supported by pillars cut in the rock, with Ionic or Corinthian capitals. The chamber is sometimes also ornamented within." If the attribution of a well-known tomb at Jerusalem to Helena, Queen of Adiabene, be correct, we have a dated instance of this kind of tomb in the first century of the Christian era, in accordance with the references to the rolling stone made by the Evangelists. The *loculus* tombs occur during the Byzantine period, but are not found in the crusading cemeteries.

The third class of tomb is the rock-sunk tomb, which is a shaft sunk in the rock, with an arched recess on either side, in which two bodies can be deposited. The earliest examples found by Lieut. Conder are connected with Byzantine monasteries. No indication has been found of the use of this kind of tomb by the Jews, unless it be taken from the account of the tomb of Lazarus, in the fourth Gospel, which is called a *spelæum*, with a stone that lay on it. The natives of Syria call this third group Frankish tombs.

The only relic of Jewish architecture further mentioned by Lieut. Conder (omitting for the present any question as to the sites of the high sanctuaries at Jerusalem and at Hebron), are the vineyard towers. "These buildings are generally about fifteen feet square outside, and the same in height. The walls are of unhewn blocks, four feet or five feet long; the roof, supported on a buttress, is of slabs seven feet or eight feet long. These solid and rude buildings occur near rock-cut wine-presses and ancient tombs."

The Great Works of Herod the Great at Cesarea, Samaria, Ascalon, Antipatris, Jerusalem, and Herodium have almost entirely disappeared. It is only at Jerusalem and Hebron that megalithic masonry, with the draft and dressing of

the stones which are peculiar to Palestine, now occurs. The aqueducts attributed to the same period are of small masonry laid in excellent mortar. Exact information as to all these architectural points will be accessible when the memoir, now in course of preparation to accompany the Ordnance map of Palestine, is published. That work will be found to contain a perfect mine of information for the architect. Plans have been made of all ruins of any importance. The size and mode of dressing of the masonry has always been noted, with the character of the mortar, and other particulars. Mouldings of capitals, cornices, and bases have been measured, and sketches made of tracery. Photographs of architectural details have in many instances been taken.

The peculiar drafting of the enormous blocks forming the walls of the High Sanctuary at Jerusalem is known to most of those interested in the subject, from photographs. We must await the early publication of "Tent Work in Palestine," announced by Mr. Bentley, for more full description of this unique, or almost unique, masonry, and for a statement of the evidence as to its anterior and posterior dates. There is also a drafted masonry of the Byzantine epoch, between A.D. 326 and A.D. 636, during which period Palestine was covered with Byzantine monasteries and chapels. Of this there is a dated example in the walls of the fortress built by Justinian round Zeno's Church on Mount Gerizim. The masonry is, however, entirely different from that at Jerusalem. The draft is deeper and broader, irregularly cut, and finished with an entirely different dressing. Semi-circular arches accompany this masonry, with narrow key-stones, and broad voussoirs at the haunches. This is also the case with the tunnel vaulting of the churches, as in that of St. John at Beit Jibrin. Another peculiarity of this age of building is the use of a large and heavy lintel, generally marked with a cross, and almost invariably present over a doorway; although the weight is very usually taken off by a relieving arch above. In some cases these enormous stones are the only relics that remain to tell of the site of a former building. Sometimes these lintels were inscribed. At Khoreisa the surveying

party found one bearing the Greek text, "This is the gate of the Lord."

The crusading epoch in the greater part of Palestine, as far as building is concerned, extends from the building of Toron (now Tibrin) in 1104, to that of the church at Nazareth in 1187. On the coast, however, there are later structures of Christian origin; the restoration of Cesarea dating in 1251. In the Eastern Crusading buildings, one of which is the hospital at Jerusalem, we find heavy mouldings and semi-circular arches. In the Convent of St. Marie la Grande the arches are slightly pointed, and there is a dog-tooth moulding resembling those common in English churches. At Samaria the round arch has been used as late as the latter half of the twelfth century. At Beit Jibrin, the remains of the Church of St. Gabriel, built about 1134 A.D., have slightly pointed arches, rising from heavy pillars and cornice. Imitations of Corinthian capitals occur in most of the earlier Crusading churches; and from the fact of their exact similarity to one another in the same church it is inferred that they were the work of the twelfth century masons, and not the spoil of earlier buildings.

Growing later, the architecture becomes more light; beautiful clustered columns replace heavy pillars, and ribbed groining is introduced. The arches are always pointed, with distinct voussoirs. The Corinthian capitals are succeeded by others of an endless variety of form, leaves, varying from smooth to deeply serrated, being the usual ornament.

Diagonal dressing is one characteristic of Crusading work. At least, this mode of finish is not found at an earlier date. It was not always employed, however, by the twelfth-century builders. A rough kind of diagonal dressing is also found on Saracenic work, but it is possible to distinguish the two. The use of the toothed chisel prevailed, as was the case at the same date in France and in England. Masons' marks, including every letter of the alphabet except D, G, Q, and X, also abound in this work, as well as inscriptions. A collection of masons' marks is given in the Memoir. The exterior walls of Crusading fortresses are of massive ashlar. They are almost invariably drafted, with a rustic boss, which projects sometimes a foot from

the draft. This work is perfectly distinct from both the Jewish and the Byzantine drafted masonry.

The Saracenic work is known by its small and less finely cut masonry, by the absence of masons' marks, by the pointed

arches, and by the low relief of the ornamental designs. There can be no doubt that the publication of the Memoir to the Map of Palestine will be a very valuable contribution to the history of the craft of the mason.

## ON STRAIN AND FRACTURE IN BARS OF VARIOUS MATERIALS.

By MR. W. J. MILLAR, C. E.

From "Iron."

IN a former paper upon "Strength and Fracture of Cast Iron," the author pointed out the connection between the form of fracture and the position of fracture in cast-iron rectangular bars when exposed to a breaking weight at the middle of span. In the discussion upon that paper, Professor James Thomson brought forward some interesting facts regarding fractures in other materials, and instanced certain substances, the forms of fracture in which would repay further investigation. Some remarks were also made on supposed connection between the forms of fracture and the neutral layer existing in the bar undergoing strain, and it is more in reference to this latter question with which the present paper has to deal. The author has made several experiments with bars of sealing wax and glass, and the following results have been obtained. Ordinary sticks of sealing wax were placed so as to rest at or near their ends, and were then loaded in the middle; the loads were gradually increased until fracture took place. The fractures so obtained were curved and removed from the center, and these curved or horned fractures pointed towards the center of span, or point of application of the load. Several bars of plate-glass were tested in the same manner, and broke with fractures having forms and directions similar to those of the sealing-wax bars. In these respects the bars of wax and of glass behaved similarly to the cast iron bars described previously. To determine the position of the neutral layer in cast-iron test-bars experimentally presents considerable

difficulty, owing to the small amount of deflection, and consequent slight change of figure, no change having been observed upon the dimensions of bars tried in this way, although measurements were taken to  $\frac{1}{1000}$  of an inch.

At first sight it may seem probable that since cast iron is about six times stronger in compression than in tension, that, therefore, the neutral layer would lie much nearer the compressed than the stretched side. The views of the best authorities on this subject are in favor of the position of the neutral layer being in the center of gravity of the section, which, in a rectangular bar, would be at the middle of the depth of the bar.

The object of the present paper is mainly to show that from experiments which have been made upon glass bars, we may infer the position of the neutral layer in cast iron bars. It has been found, when a bar of glass is subjected to strain and submitted to the action of polarized light, that the neutral layer can be seen, and that it lies midway between the two sides of the bar. Mr. Spottiswoode, in a lecture delivered on "Polarized Light," in 1873, says, speaking of a bar undergoing bending:—"The side towards which it may be supposed to be bent is, of course, compressed while the opposite is stretched out. Between these two there must be an intermediate band, more or less midway between the two, which is neither compressed nor stretched. The moment the strain is put upon the bar, light will be seen to pass through the parts of the bar nearest to both sides, while a band remains dark midway between the two."

An illustration of this was given by Mr. Spottiswoode at his lecture on "Polarized Light," Glasgow Science Lectures, 1877. A description of similar experiments will be found in the Transactions of the American Society of Civil Engineers, vol. iii.

Now it appears, from experiments by Messrs. Fairbairn and Tate, that the resistance of glass to compression is about twelve times its resistance to extension, so that if we were to argue from the ratio of these strengths as to the position of the neutral layer, we might expect to find the neutral layer very close to the compressed side; the experiments, however, with polarized light, conclusively show that the neutral layer is midway between the compressed and extended sides. Again, since curved forms of fracture are found to occur in glass bars whose neutral layer is situated as described, it appears that the form of fracture in these bars gives no indication of the position of the neutral layer, but that they simply indicate, as in the case of cast iron bars, the position at which the fracture has commenced, viz., removed from the center of span. We may, therefore, fairly argue that the neutral layer in cast iron bars lies mid-

way between the compressed and extended sides.

The author had been unable to find from already recorded experiments the relative strengths in tension and compression of sealing wax, but from an experiment made with a view to determine this, it appears that the tensile strength of sealing wax is about 210 lbs. per square inch, whilst the compressive strength is over 1,500 lbs. per square inch. From the foregoing experiments it appears that the modulus of rupture of plate glass is about 7,400 lbs. per square inch, and that the modulus of rupture of sealing wax is 1,370 lbs. per square inch. The average breaking strength of the 81 cast iron bars formerly described was 3,571 lbs., from which it appears that the modulus of rupture is 48,000 lbs. per square inch. The various moduli of rupture are calculated by equating the bending moment and the moment of resistance.

$$\frac{W \times S}{4} = \frac{R \times B \times D^2}{6} \text{ or } R = \frac{3 \times W \times S}{2 \times B \times D}$$

where W is the load in lbs., S the span in inches, R the modulus of rupture in lbs. per square inch; B the breadth in inches, D the depth in inches.

#### ON STRAIN AND FRACTURE.

A diagram was exhibited showing the strain and fracture in bars of various materials, as ascertained by experiment, which we give in a tabular form:

	Dimensions of Bars.					
	Span.	Breadth.	Depth.	Breaking Weight.	Deflection	Modulus of rupture.
	in.	in.	in.	lb.	in.	lb. per square in.
Glass fractures.....	9.312	0.20	0.34	12	—	7250
Glass fractures.....	9.312	0.20	0.32	12	0.075	8192
Glass fractures.....	9.312	0.20	0.37	13	0.075	6637
Glass fractures.....	9.312	0.20	0.32	11.5	0.080	7843
Glass fractures.....	9.000	0.20	0.32	10.7	—	7053
Sealing-wax fractures .....	7.000	0.35	0.375	6.5	0.32	1392
Sealing-wax fractures .....	7.000	0.36	0.36	5.75	0.56	1249
Cast iron fractures.....	36.0	1.00	2.00			
Cast iron fractures....	36.0	1.00	2.00			
Cast iron fractures.....	36.0	1.00	2.00	Mean of 81 bars. 3.571	Mean of 81 bars. 0.392	Mean of 81 bars. 48,000

The breaking weights were obtained by means of a graduated lever and sliding weight, and the deflections by an extension of one of the lever ends, which traced a line upon a piece of smoked pasteboard. As the knowledge of the

position of the neutral layer in a beam is of considerable importance to the engineer and shipbuilder, seeing that the moment of inertia, and the consequent moment of resistance, are calculated by rules depending upon the position of the neutral axis of the section whose strength is to be determined, it is hoped that the foregoing may prove interesting to the members of this Institution.

In the discussion which followed the reading of the above paper, Mr. E. Kemp asked whether in his experiments Mr. Millar had tried any other substances but the three mentioned?

Professor Thomson said it was to Mr. Millar that they were indebted for the discovery, that there was a special connection between the place where the load was applied, and the side to which the horn turned in breaking—that when a bar was supported at two ends, and loaded in the middle, the crack seemed to open at the bottom, and the horn pointed to the place where the load was. The fact of horned fractures occurring in connection with the breaking of sealing wax was well known long ago. He had tried it with regard to the basaltic rocks; but, so far as he knew, the connection between the place where the load was applied, and the direction to which this horn turned over had never been specially noticed until now. This was a fact well worthy of being noticed, and a reason sought for it.

Mr. Rowan said it would appear that strains were very capricious in the breaking of these crystalline substances; though none of them broke at the same place, there was a strong family resemblance in the fracture—a fact which perhaps they would never be able to explain. He remembered having to use malleable iron bars, and he could not find reliable data to go by; Mr. Millar could give nothing suitable, and accordingly some experiments had to be made. He asked whether Mr. Millar had taken any notice of them in his paper?

Mr. Millar said he had made some reference to those experiments in his previous paper.

Mr. Rowan said one curious thing was noticeable—the diminishing deflection that took place.

In one malleable-iron bar  $\frac{17}{16}$  thick, two inches broad, two inches deep, and three

feet between the supports they increased the weight to thirty-seven cwt. By occasionally taking off the load it diminished the deflection, which altered each time, until ultimately they had a permanent set. It was quite appreciable, but that was about the limit of that forged malleable iron bar.

Mr. W. R. M. Thomson asked whether Mr. Millar had artificially assisted the breaking of the bars by a slight cut or scratch, at the different distances from the center.

Professor Thomson said one point touched upon in the paper had been discussed in other places, and in books of recent years, namely, as to the position of the neutral lamina. A good deal of confusion had arisen in regard to that as to the difference between breaking a rod under compression, by elastic yielding to compressing force, and not yielding to force. The fact that cast iron will break with much less stress per square inch by tension than by compression, had nothing to do with their yielding more in elastic limits under tension and compression. They had a right to be very certain that the yielding to tension and compression within the elastic limits were just alike.

Mr. R. Mansel said it was very clearly shown by the experiments with polarized light that the section of the neutral plane in glass was near to the center of gravity of the particular section.

Mr. Millar replied that when conducting these experiments the bars could be noticed at times, when near the breaking load, to take a sudden depression and then to break. Mr. Kemp had asked if he had used any other substance in his experiments? He had not done so. The chairman had spoken of the position of the neutral lamina, as it was important for engineers to know its position when calculating the moment of resistance of a section. In the glass bar referred to under the action of polarized light, exhibited at the lecture by Mr. Spottiswoode, so far as he could observe there was no movement of the position of the neutral layer, even though the bar happened to break; it remained midway until the bar snapped, so that apparently the neutral layer lay midway between the sides until the fracture took place. His object in connecting these experiments upon glass bars with cast iron was,

that from the difficulties of dealing with cast-iron bars the deflections and consequent change of figure being so small, much information might be got from the glass bars of what occurred in the cast-iron bars; and seeing that the ratio of compressive strength to tensile strength in glass is about double of what it is in cast iron, and that both substances showed fractures following the same general law, the inference was very strong that the neutral layer of cast-iron bars would lie midway between the compressed and extended sides. Mr. Thomson had asked whether he had attempted to fix the position of fracture by weakening the bar at a particular part. He had not done so with these bars, but he had often done it with cast-iron bars, and the form of fracture had always followed the law of the curve pointing to the center. In some cases he had file draughts made on the cast-iron bars to about the 16th of an inch deep, but the bars had not always broken there. In his former paper

he had given what he believed to be the reason for this particular kind of fracture and had demonstrated the same by diagrams of lines of stress. His theory, shortly stated, was that fracture commenced at the extended side, and that as the lower layers were in tension the direction of fracture would be at right angles to the direction of this stress, which would give a fracture running up to the compressed side. If the fracture took place at center of span there would be equal actions on each side; hence a straight fracture would ensue; but if fracture commenced away from the center, the line of fracture would at first follow the same direction as before; but since the longer part of the bar, by reason of its greater curve, would have more spring in it than the shorter part, an unequal action would arise, which would tend to form a fracture running horizontally; the resultant action would therefore give a fracture of the curved forms exhibited.

## RIVER IMPROVEMENTS IN FRANCE, INCLUDING A DESCRIPTION OF CHANOINE'S SYSTEM OF FALLING GATES.

BY PROF. WILLIAM WATSON, Ph. D., late U. S. Commissioner.

### II.

NEARLY all the new barrages on the rivers Seine and Yonne have passes closed by Chanoine's system of falling gates (*Hausses mobiles du système Chanoine*).

Chanoine's barrage consists of two essential parts, viz., a navigable passage, and an over-fall or waste weir.

The navigable pass serves, when there is a sufficient draught of water, for navigation; the gates being at that time lowered upon a solid bed of masonry prepared for their reception at the bottom of the river.

The weir serves to maintain the river at a constant height, when the gates are raised, by providing for the discharge of the surplus water.

To these essential parts there is usually added a lock, through which the boats pass when the gates are up.

The pass is closed by a series of falling

gates, the invention of M. Chanoine, which may be thus described.

*Chanoine's falling gate*, Fig. 6, consists of a rectangular wooden pannel framed and strongly clamped with iron, revolving on a horizontal axle placed perpendicular to the current.

This pannel is divided by the axle into two parts, the upper, called the chase, and the lower, the breech; to the bottom of the latter a strong wrought iron handle is securely bolted.

The chevalet, or horse (Fig. 3), which supports the pannel, has the form of a trapezoid; the two uprights being connected by one or more horizontal transoms.

The axle of the pannel which forms the cap E of the horse is finished with turned journals, which are held by two cast iron collars secured to the pannel by screw-bolts, nuts and washers. The

lower bar F has also journals which turn in bearings firmly attached to the sill. The height of the horse is about  $\frac{5}{12}$  of the height of the panel, hence when the horse is folded down the panel folds over it and both lie flat on the platform (Figs. 1 and 2.)

When the barrage is closed the horse is erect, and the panel abutting against a sill 0.10 m. above the platform makes an angle of about  $82^\circ$  with the horizon; it is sustained in that position against the pressure of the water by a strong wrought iron abutment prop *a e* hinged

Fig. 1. Elevation and section.

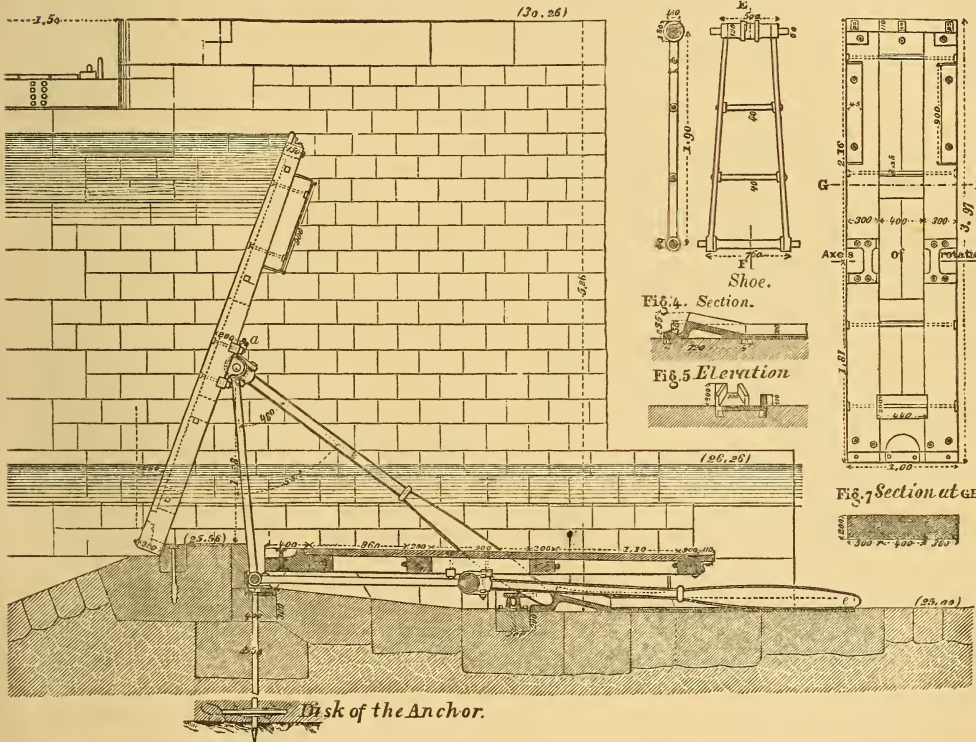


Fig. 2. Plan

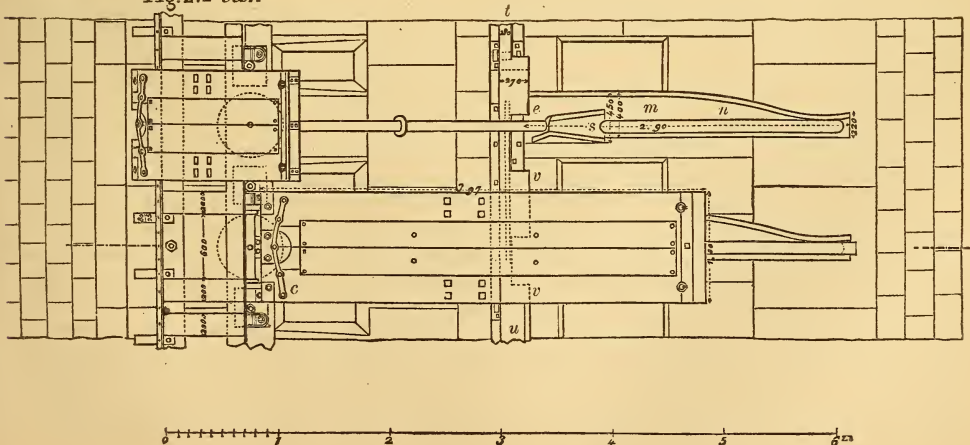


Fig. 3. Horse.

Fig. 6.

Section E F. Elevation.

Panel.

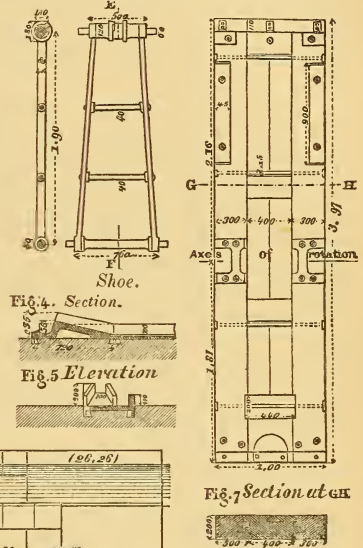


Fig. 4. Section.

Fig. 5. Elevation

Fig. 7. Section at G H

to the cap of the horse at *a*; its foot *e* is held by a cast iron shoe or heurter *s* firmly fixed in the masonry platform. This shoe is open at one side to allow *e* to be drawn out into a guide plate *m n* when the gates are lowered. The joint *a* between the prop and the horse, is thus formed; two cheeks are welded to the cap of the horse and between them, the head of the prop is placed and held in position by the pin *a*; to allow the lateral motion of the foot of the prop, the hole at the head of the prop is made larger than the pin *a* which connects it with the horse.

*Talon-Bar.*—The displacement of the foot *e* of the abutment prop from its support *s* is effected by means of a long horizontal bar *t u*, called a talon-bar, furnished with projections or talons *v v* (Fig. 2) placed at suitable intervals.

This bar is terminated at one end by a rack which gears with a pinion attached to a capstan fixed into the abutment or pier at the end of the barrage; this bar runs on rollers and is so arranged that it can be brought back to its initial position when the gates are lowered.

*Method of Lowering the Gates.*—If, on account of a freshet in the river, the barrage is to be lowered, the ends of the abutment props are drawn out of their shoes by the talon bars put in motion by men heaving on the capstans; as soon as a prop loses its point of support it slides along the guide plate *m n*, the horse turns the pannel, follows and covers it (Figs. 1 and 2), and the water flows freely over both.

There should always be several decimeters of water on the platform, when this maneuver takes place, to deaden the fall, otherwise the gate would be liable to fracture.

*Method of Raising the Gates.*—The gates are raised by means of a windlass built into a boat 8 m. long and 2.20 m. wide, made of oak and specially constructed for the purpose; the boat is fitted with a large sheave or pulley at its stem head, and supplied with ropes, fenders, keys, and grappling hooks.

[NOTE. *Fenders.*—The fenders consist of two iron frames hinged to the side of the boat, one forward and the other aft, and terminated by wooden buffers long enough to support the boat against the lifted pannels. Upon these

fenders a service bridge is erected, high enough to enable the lockman to examine the down stream side of the gate and assure himself of the position of the abutment prop.

*The Keys.*—Each key is an iron bar in the form of a T, and is placed within reach of the man at the windlass. The handle of the T is held in a socket let into the gunwale of the boat, and the other end is inserted between the gates.

*The Grappling Hook* is an iron hook with a long wooden handle; to this hook one end of a long chain is made fast; the other end is carried around the pulley at the stem head and secured to the barrel of the windlass.]

In order to raise the gate next the bank, the boat is placed parallel to the abutment, with its bow projecting half the width of the gate, and secured in this position by ropes; it is also kept at a proper distance from the gate by fenders. When all is ready the lockman puts the grappling hook into the handle of the gate, and his assistant at the windlass slowly winds in the chain; the pannel rises, the horse turns through a quadrant, the abutment prop follows and falls into its place in the cast iron shoe. The pannel in this position is nearly horizontal, the counterpoise, or a slight pressure, brings the breech down and the pressure of the water forces it into its place against the sill; its motion, however, is here moderated by slowly unwinding the chain. The abutment prop is examined to see if it is exactly in its place, and the grappling hook detached from the pannel.

As soon as one gate is raised the boat is pushed forward the width of a gate, and the operation repeated until the pass is entirely closed.

The interval between successive gates is about 0.10 m., hence by inserting the keys, using the fenders, and also with the aid of ropes fastened to a pier or abutment, the boat is held securely throughout the whole operation. Only one gate can be raised at a time: it takes from four to five minutes to raise each gate.

Each of the twenty-two new barrages has a pass closed by Chanoine's system of falling gates, worked by means of a talon-bar and a boat. Thirteen of these barrages have an overfall held by falling

gates, the pannels being worked from a bridge resting on a system of *fermettes*. In six, the overfall is surmounted by *fermettes* and needles with a foot-bridge 0.25 meter above the upper bay; one has Girard's system, which will be hereafter explained in detail. The sills of these passes are generally placed 0.50 or 0.60 meter below the level of the lowest water.

#### FIXED PORTIONS OF THE BARRAGES.—

The width of the foundation of the upper bay of the pass of the new barrages with falling gates is from seven to ten meters up the stream; its thickness is at least equal to the fall and rarely less than two meters. Between Auxerre and Joigny it rests directly upon the rock or chalk. Between Joigny and Montereau the mass is formed of a layer of *béton* poured into a coffer-dam, and upon this mass after the dam had been pumped out the foundation and bed of the upper bay were built, which is partly of cut stone and the rest of rough stone dressed at the joints. In the bed of the upper bay are fixed anchors, consisting of wrought-iron bars and cast-iron plates serving to solidly unite the masonry and the wooden sill against which the bottoms of the pannels strike. The bed of the overfall of these new barrages is usually four meters wide, and has a minimum thickness of two meters. It is either entirely of masonry or else a wooden coffer filled with *béton* and covered with a masonry pavement.

The overfall or wier lies between a masonry pier 3 m. thick, and 6 m. long, which separates it from the pass, and a masonry abutment connected with the bank by two wing walls.

Below most of the barrages there is a rear bed, or apron, composed of rip-rap kept in place by piles driven in quincunx.

#### MOVABLE PORTIONS OF THE BARRAGES.

—The navigable passes of the twenty-two new barrages upon the Yonne are closed by wooden gates 1.25 meters wide and 0.05 meter apart. During the season of low water the interstices are stanchied by *couvre-joints*, i.e., pieces of timber 0.25 meter to 0.30 meter wide, and 0.03 meter thick placed above against the pannels. The overfalls of fifteen of these barrages when constructed, were furnished with the auto-

matic gates of Chanoine; these were 1.35 meters wide.

CHANOINE'S SYSTEM OF AUTOMATIC FALLING GATES.—When a pannel is erect, as long as the resultant of the pressure of the water passes below its axis of rotation it remains erect; if, however, this resultant should pass above the axis of rotation the pannel would overturn. We may thus divide the gates into two classes according to the relative positions of their axis of rotation; these classes are designated by M. Chanoine as automatic and non-automatic gates.

It is evident, that as the center of pressure of the water on a rectangle is situated at one-third its height, if the axis of the pannel is so placed that the length of the chase is twice that of the breach, the pannel will turn spontaneously when the water rises to the top. It may be brought back when the water has fallen by the action of a suitable counterpoise.

The pannels of the pass have their axes of rotation higher up than those of the overfall and do not fall spontaneously, but by the aid of talon-bars moved by capstans; they are raised by a boat.

The pannels of the weir, on the contrary, were made to fall and rise themselves, on account of the position of the axes of rotation, which is 0.05 meter, above one-third the height of the pannel, and by the action of a suitable counterpoise. The ingenious system of automatic gates for the overfall was at first highly esteemed on account of its simplicity and its success on a single barrage, as a means of disposing rapidly of the surplus water of a freshet without emptying the upper bay or interfering with the navigation of the stream; but great difficulties arose when it was tried in 1868, on a large scale, for the continuous navigation of the Seine and Yonne between Paris and Laroche. The floods of the *écluses* from the Yonne, which were ponded above Laroche, or a little freshet, produced disturbances in the upper bays and overturned all the automatic gates; that is to say, an elevation of water from 0.09 to 0.14 meter above the crown of the pannels was sufficient to overturn them. They did not shut again until the water had fallen 1 meter in the upper bay, thus stopping

navigation and exposing the barges to grounding.

Notwithstanding the zeal and devotion of the lock-men and employés of every grade, it was impossible to prevent this disorder as long as the gates were not worked directly by the lock-men themselves; hence the engineers did not hesitate to propose the establishment of service-bridges above the overfalls with gates; this proposition was approved in 1868 and carried into effect in 1869 and 1870.

The SERVICE-BRIDGE is composed of iron *fermettes*, like those of the needle barrages, of Poirée, movable round a horizontal axle perpendicular to that of the overfall. Each *fermette* corresponds to the axis of a pannel. These *fermettes* are united at their tops by two connecting-bars, which limit the width of the walk; between these bars a flooring is placed 0.50 meter above the level of the water. The two connecting-bars are rails upon which the crab-engine rolls. Finally, to this crab-engine are attached two chains, one to the upper and one to the lower edge of each pannel. By the aid of the crab made fast to one or two *fermettes*, and with the two chains, every necessary manœuvre is made without fatigue and without danger. In times of freshet, the connections between the *fermettes* are taken off in succession, commencing at one end. The first frame, relieved of all connections, revolves on the axis at its base and falls into a chamber in the platform on the bed of the river. The second frame is then disengaged and lowered over the first, and so on to the end; the height of the frames being greater than the interspaces, they lie partly over each other in the chamber prepared for their reception in the platform on the bed of the river, and in which they are below the level of the sill, and so protected from injury. The frames next the wing-walls fall into a recess in the masonry. The bars and the crab are stored. It is alleged that the gates of the overfalls should not have counterpoises. These service-bridges have been also established at the two old overfalls of Pechoir and Saint Martin, which have a special kind of gate movable around an axis fixed to the up-stream crown of the overfall.

The new system has been a perfect success. Every night the lock-man is warned of the variation of the water in the upper bay by an alarm put in motion by a floater. In addition, all the barrages are united by telegraph, and the system, thus complete, prevents all surprise.

The experiment made in 1868 upon the working of the twenty-nine barrages constructed upon the Seine and Yonne has served as a basis for the new plans for improving the Yonne between Laroche and Auxerre. New barrages were planned with a movable pass closed by falling gates, and an overfall with needles and *fermettes*. Six of the barrages between Laroche and Auxerre have this system of overfall.

#### LOCKS.

*Dimensions, form, and mode of construction.*—The three old locks have their walls vertical of solid masonry; the head-walls are 2.50 meters thick. Fifteen of the new locks have the heads and masonry gate-chambers with vertical walls, the rest of each lock-chamber is included between two walls, whose outer faces, sloping at an angle of 45°, are protected by stone pitching. They rest upon a mass of sheeting or masonry, reposing either upon a solid bottom or secured by rows of piles and sheeting.

For the river-locks, the dike which forms the side-wall is three meters thick at the top, with an exterior side-slope of  $\frac{3}{4}$ , protected by stone pitching. The coping is masonry. The dike, constructed of earth, with a central core of rammed clay two meters thick, is generally very tight.

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M. MILNE-EDWARDS has been elected President of the Scientific Association of France, created by M. Leverrier. The Association has organized a series of lectures at the Sorbonne, to describe new inventions and discoveries. M. Cailletet's experiments on the liquefaction of oxygen, air and hydrogen will be exhibited at the first meeting, which will soon take place. They will be explained by M. Henri St. Claire Deville. It is stated that M. Dumas intends to propose a subscription for erecting a monument to Leverrier.

## PROFESSOR SKINNER UPON MOMENTUM AND VIS VIVA.

By S. BARNETT, Jr., Edinburgh, Scotland.

Written for VAN NOSTRAND'S MAGAZINE.

WE do not propose to review the whole of this article (VAN NOSTRAND'S MAGAZINE, Nov. & Dec., 1877), but only such parts as relate to Prof. Tait's lecture upon Force before the British Association at Glasgow, printed in *Nature*, (Sept. 21, 1876). The mistakes into which Prof. Skinner has fallen arise principally from two causes; a misunderstanding of the question to be solved in establishing an absolute unit of force, (for, he says, he can see no reason why the absolute unit should be called so), and an excess of zeal for controversy. After mentioning various views of force by different writers, he says, "and we have lately had the eminent Prof. Tait define it as the *rate of doing work*." Prof. Skinner asks, as if conclusive of the matter, whether the weight of a penny letter, the unit of force, "can be regarded only as a *rate of doing work*." It may appear to the unscientific at first sight a little artificial so to define force. But this is so only because the unscientific are unaccustomed to define force at all. The day laborer who works from morning till night would consider it extremely absurd if you were to tell him that work was the product of the resolved part of the force along the line of displacement into the displacement. There is a vast difference between knowing generally that a force is "any pull, push, pressure, tension, attraction or repulsion," and being able to establish a unit of force which can be found at any time or place, even though, however improbable such an occurrence may be, all spring balances and platinum units of mass should be simultaneously destroyed, and the earth itself should suddenly contract or expand in volume. Prof. Skinner either does not see that this is necessary to a unit of force being absolute, or he completely ignores it.

Instead of rate of change of momentum or rate of doing work, Prof. Skinner calls force a *pressure or tension* measurable in pounds. He goes into quite an elaborate argument, quoting from Newton, and giving the results of experiments with

Attwood's machine, to show that *force* is simply *pressure* or *tension*. Yet how are we benefited by this knowledge? We know force as well as tension, and it would have been equally instructive to prove that *tension* was *force*. By this, however, he means to prove that inasmuch as force is tension it is not the rate of doing work. Prof. Skinner seems to forget that it is necessary for him to know what tension is before he can say what it is not. It should be remembered that the pound is not a weight but a mass, viz., the platinum block kept at London, in the Exchequer Chambers. The pound weight, however, is a force, yet a variable one. The pound weight is different at different parts of the earth, and different at the same place at different times unless the dimensions of the earth are rigorously invariable. A unit of weight then is a delusion; there is, and can be, no such thing. Yet Prof. Skinner assuming the usual units of time, length and mass, proposes as follows to *derive* the unit of force from them; for, choosing any three of these four at pleasure, he says "nature imposes a connection between the fourth and the others," and, therefore, this fourth can be derived. And this he does by assuming the unit of force to be equal to the weight of the unit of mass in the place where it is kept. But this weight will vary with possible variations of gravity at London. To render the unit of force independent of this, Prof. Skinner proposes at a particular time to provide a spring balance and note the distortion due to the weight, and to define the unit of force, the force due to this distortion. The reader may have noticed that this makes the unit of force depend solely upon the perfection of a dynamometer, independently entirely of the units of time, length and mass; Prof. Skinner has thus by two steps severed the connection which nature had imposed. But the most significant fact is the method by which Professor Skinner proposes to establish a check, or to verify his spring dynamometer

He says, "the results of this weight, at the given time, in maintaining the distortion of a spring, and in producing motion could, of course, be recorded."

Evidently, the recording the amount of motion the spring is capable of producing, saves the necessity of postulating its perfection. But then this record dispenses with the necessity of preserving the spring; the record is necessary and all sufficient. The subterfuge of the spring serves only to blind Prof. Skinner to the completeness of his surrender to Prof. Tait's principle of measuring force by the rate of change of momentum; and not only Prof. Tait's but Newton's, and the method of the scientific world since his day.

It is hopeless to expect to establish any invariable units dependent upon aggregations of matter. The whole universe, the stars, the planets, our standards of masses, and lengths, and all spring balances are evanescent and must change some time or other. The "absolute" measure of force, to which Prof. Skinner raises objections, and of all our other units is independent of any such aggregation. The units of time and length may be made to depend upon the time of vibration and length of wave of a particular kind of light, and thus absolutely determined for all time. All the other units may be made to depend upon them. For example, the unit of mass may be defined by its relation to that mass which, by its attraction of gravitation, at unit distance, will produce unit velocity in unit time; the unit of force, as that force which by acting for unit time on unit mass will produce unit velocity; unit of velocity of course being that of a body moving over unit length in unit time. Thus the units of density, momentum, work, Potential, Electricity, etc., may all be made to depend immediately upon those of time and length.

The second law of Newton, from which the above definition of force is deduced, reads as follows: *Change of motion is proportional to the impressed force and takes place in the direction of the straight line in which the force acts.*

W. O. P. (*Nature*, Oct. 26, 1876), quoted with approbation by Prof. Skinner asks, "has not Prof. Tait confused the idea of *measuring* something with the idea of *being* something." Prof. Tait

has simply distinguished the phenomenon, which is all that an exact science has to deal with, from those metaphysical speculations which are beyond the reach of experiment. It is not pretended that the rate of change of momentum is both the first cause and the final effect; it is only the phenomenon and, therefore, all that science is to recognize. The substitution of rate of change of momentum for force in the above law renders it tautological, because it is of the nature of a real definition, embodying all that we know of force. What may correspond in the outward world to our sensations of muscular tension is simply speculation. We see only motion; even when ourselves exerting muscular tension the motion produced, not the sensation, is a measure of the force; the compression of a spring means nothing to us except what momentum it has been previously found to create or destroy. Newton here recognizes no balanced forces. Impressed force produces its change of motion. In fact when we consider that there are no fixed boundaries in space, but that motion is motion only with reference to some arbitrarily chosen fixed origin, this becomes self-evident. Every force according to Newton does work. For, if with reference to any fixed origin, arbitrarily chosen, the body be at rest, remove one force the others remaining as before; thus may be seen the work the force destroys. But the destruction of work is simply doing work in the opposite direction. The penny letter resting upon the table has work done upon it by gravity; the resistance of the table does an equal amount of work in the opposite direction. This is excessively simple and undeniable when understood.

Prof. Skinner should be careful not to claim more for Thomson and Tait than they claim for themselves. In comparing the accuracy and simplicity of the absolute units given above, with the clumsy ones adopted in many text books (*Nat. Phil.* p. 166), they observe "that the assumption of the unit of mass as  $g$  times the mass of the platinum pound gives a variable unit,  $g$  itself at London not being constant." Yet Prof. Skinner quite irrelevantly asserts that 32,1912 times the standard pound is invariable. This is quite true and may be admitted

without prejudice to any thing said by Thomson and Tait. Let us now test Prof. Skinner's unit of force in the light of his own formulæ. The formula  $M = \frac{G}{g}$  he says "will give the mass, provided  $G$  be the weight measured on a standard spring balance, and  $g$  be the acceleration of gravity at the place."

Here we have the means of obtaining the dimensions of weight and thus of discovering what Prof. Skinner's force really is. The formula gives the weight  $G = Mg$ , of which the dimensions are mass times acceleration. A weight then is simply a rate of change of momentum. Prof. Skinner then has simply stopped too short; he can verify his dynamometers only by change of momentum, and when the dimensions of weight, and therefore of force are found, force itself is found to be nothing but rate of change of momentum. This definition is implied in every equation in dynamics.

We pass on towards the last of Prof. Skinner's article. He says that he cannot agree with the view that force is a mere rate of change of momentum, and that it seems to him a sufficiently good reason for rejecting it, that the intensities of forces may be measured without having any thing to do with momentum, simply by measurements upon a spring balance, while not (apparently) doing any measureable work or changing momentum at all. The above amounts simply to saying, that we can devise an instrument, viz., a spring, by which the observer may infer the amount of work done upon a body, even when the observer and body have no relative motion. It is inconceivable that a single force should act upon a body and leave it in the same state as before. If two equal and opposite forces, as gravity and the resistance of a support, come simultaneously into action, the work done in one direction is equal and opposite to that in the other; but each force does or destroys its proper amount of work. We have run the risk of being tedious here, and of repeating, because Prof. Tait's concise treatment seems to have contained many points that have been overlooked.

Prof. Skinner says that we have as good a right to call force rate of change of vis viva per unit of distance as of

momentum per unit of time. This can scarcely be an objection, as the two are mathematically identical, and are employed indifferently for force throughout the whole of dynamics and of mathematical physics. Besides, even though Prof. Tait were not in the habit of using either indiscriminately, as he is, it would not be much of a compliment to his mathematical knowledge to suppose he had never observed the identity. Next, Prof. Skinner asks, "can the equation  $F = \frac{\frac{1}{2}MV^2}{D}$  be any part of what Prof. Tait

alludes to when he says, 'a simple mathematical operation shows us that it is precisely the same thing to say:

*"The horse-power or amount of work done by an agent in each second is the product of the force into the average velocity of the agent, and to say:*

*"Force is the rate at which an agent does work per unit of length."*

Prof. Skinner adds, "What his simple mathematical operation would be, I do not know; for I never saw it stated elsewhere that *the horse-power done by an agent in each second is the product of the force into the average velocity of the agent*, or that *the horse power in each second* is such a product, or even that *the horse power* is that product."

When Prof. Skinner says he never saw these things stated elsewhere, it is to be supposed that he thinks he sees them stated here. Prof. Tait uses as synonymous terms *horse-power* and *amount of work done by an agent in each second*. If Prof. Skinner sees in that anything about *doing a horse-power in a second*, or even a *horse-power in a second*, there is an end of the discussion; and the matter has become a mere question of sight.

It would be tedious to examine closely every objection urged by Prof. Skinner. We omit a number, and among them the question of the comparison of force and momentum. Prof. Tait in his lecture calls attention to the fact of there being of different dimensions in the units of time, length and mass, and that for that reason the mathematician would no more think of comparing them, than, as Hopkins used to say, of measuring heights in acres, or arable land in cubic miles. This seems to Professor Skinner an argument of no validity; for, among

other things, he notices that force and momentum are sometimes *numerically* equal. The same is true also of a square and a cube, but for that reason in itself they can neither be denied nor affirmed to be the same thing.

"Again, Prof. Tait says that the mathematician expresses the distinction between force and momentum by saying that 'momentum is the *time integral* of force, because force is the rate of change of momentum,'—both of which propositions" says Prof. Skinner, "appear to me objectionable." We are unable to say why he calls this "both." There is but

one proposition;  $\text{Momentum} = \int dt$ , because  $\text{Force} = \frac{d}{dt} (\text{Momentum})$ . We do

not ask why he calls it both from a desire to criticise small points, but if possible to throw light upon what Prof. Skinner understands a time integral to be. We find next the following: "I have already given some reasons for rejecting the idea that force is a mere *rate of change*; and how can momentum be properly said to be the *time integral* of force, when *any amount* of momentum can be produced in *any time* by a force of the proper intensity? It appears to me that the *integral* of any quantity ought to be equal to the sum of all its increments from zero. But a *constant* force can have no increment and therefore no proper *integral* dependent on time." We cannot imagine what Prof. Skinner understands by a time integral. The time

integral of force is really  $\int_b^a F dt$ , where

$F$  is a function of  $t$ . Prof. Skinner certainly will not maintain that this integral can not be finite when the limits of integration are infinitely close together; or that the above is no proper time integral at all when  $F$  is constant? It is possible he had some other integral in mind, especially as he says that an integral is the sum of all its increments from zero, and this is true only of the

simplest possible of all integrals  $\int_a^x dx$ .

But even granting with him that a constant force has no proper time integral what are we to say of the following? Since then, he says, a constant force has no time integral, let us consider a variable force. He then lets a force equal to one pound act for the first second, a

force of three for the next, five for the next, etc. For these he finds a proper time integral. That is, though a constant force has no proper time integral, the sum of a number of these improper or impossible quantities gives as a result a proper time integral. Now any one who adopts a unit of force different from the one given by Prof. Tait necessarily finds himself involved in some inconsistencies; but has not Prof. Skinner needlessly complicated matters?

"Prof. Tait asserts that force is not an objective reality but a convenient abstraction—a mere name—and that the *product of a force into the displacement of its point of application* has an objective existence. How the product of a mere name into the *displacement of its point of application* can have an objective existence, while that which the name denotes cannot, I leave to the metaphysician." Prof. Skinner here, for the sake of argument, grants that force is merely a rate of change, and he thinks it necessary immediately to introduce the metaphysician. For our own part we consider the metaphysician entirely superfluous. The death rate into the number of people in a city will give the number likely to die there in a year.

The following quotation shall be our last, "Prof. Tait, at the end of his lecture, says, that 'in defense of accuracy, which is the *sine qua non* of all science we must be zealous as it were even to slaying.' Whether the points of the lecture to which I have called attention are merely slips, due to the unpropitious circumstances of time, place and surroundings, under which he says the lecture was prepared, or whether he would if he thought it worth while show that my objections are groundless, I do not venture to say. But if his position is not sound, the high and well earned fame attached to his name may make the lecture a source of much future confusion, so that I have thought it worth *my while* to consider it here at some length."

We are sorry that Prof. Tait's "zeal" in "slaying" has not yet called forth anything further from him. Possibly he considers his position sound, and trusts that, though on a first reading a few old notions may be uprooted, a careful study of his lecture is not likely to produce confusion, but on the contrary, quite the reverse.

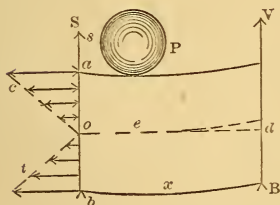
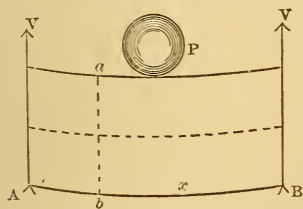
## NOTE ON THE MISAPPLICATION OF CORRECT THEORIES.

BY DE VOLSON WOOD, C. E., M. A.

Written for VAN NOSTRAND'S MAGAZINE.

In the last December number of this Magazine, on page 524, Mr. Crehore states that "I suspect that no late authority disputes the equality of the total moments on each of the two sides of the neutral surface."

If the Science of Statics is correct, the equality of moments here assumed is impossible. Take the case of a beam supported at its ends and loaded at the middle. The vertical reactions at each end will be  $V = \frac{1}{2}P$ . These forces develop internal stresses. Make a vertical section  $ab$  at a distance  $x$  from the end  $B$ . Remove the part  $Ab$ , and in the sec-



tion  $ab$  introduce forces which produce exactly the same strains on the elements of the beam as existed before the section was made. According to the principles of Statics the algebraic sum of the vertical forces will be zero; hence, according to the notation in the preceding figure, we have

$$S_s + P + V = 0$$

Let  $P$  be position downwards, then will  $V (= \frac{1}{2}P$  in this case) be negative, and we have

$$S_s = V - P = -\frac{1}{2}P$$

which being negative shows that it acts

upward. The vertical force in the section is called a *vertical shearing stress*.

According to the same principle of Statics, the algebraic sum of the horizontal forces will be zero for equilibrium. The only horizontal forces in this case are the pulls and pushes of the forces in the section. Let  $t$  be the sum of tensile forces, and  $c$  the sum of the compressive forces in the section  $ab$ , then we have

$$t + c = 0$$

$$\therefore t = -c;$$

or they must be equal and contrary. These forces are equivalent to a couple.

Lastly, according to Statics the algebraic sum of the moments of all the forces in reference to any point must be zero. Take the origin of moments at  $o$  on the neutral surface. The forces producing tension tend to turn the system in the same direction as those producing compression,—in this case right-handed—hence they have the same sign and cannot be equal to each other. Draw  $od$  horizontal, and take  $e$  directly under  $P$ ; then will  $oe$  be the arm of the force  $P$ , and  $od$  that of  $V$ .

Also let  $T$  be the resultant of the tensile forces, and  $f$  its arm, and  $C$  and  $g$ , the corresponding quantities for the compression ones, and we have

$$T.f + C.g + P.oe - V.od = 0$$

The values of  $P$  and  $V$  cannot both be made to disappear at the same time from this equation, hence we cannot even have

$$T.f = -C.g$$

for equilibrium. Therefore, we see that the hypothesis that these moments equal each other must be erroneous. Neither does it help the case by showing that the equation founded on this hypothesis, represents the results of experiments exactly, unless, indeed, we are prepared by such a coincidence of results to overturn the fundamental principles of Statics. The truthfulness of these equations and conclusions should not, therefore, be

called in question any more than we should deny the soundness of the laws involved in Maclaurin's and Taylor's Series, because these laws are not applicable to all functions. But the laws of Statics would indeed be applicable to the case if the law of action of the internal stresses were known. After the strain passes the elastic limit, it is certain that the stresses do not increase directly with the distance from the neutral axis. It is not probable that the neutral axis remains at the center of the cross sections at the time of rupture, and this combined with the fact that the law of the stresses is not only complex, but really unknown, prevents us from establishing the true equation of rupture. The only thing necessary in order to make a correct theory in regard to rupture, is to determine the correct law of action of the internal stresses at the instant of rupture.

Navier, in his earlier lectures *assumed*

the equality of moments on opposite sides of the neutral surface, but in the second edition of his work the correct statement was substituted for it,—that the *forces* on the opposite sides were equal. Similarly, Barlow, several years after Navier's correction, assumed the same error in regard to the equality of the moments. In neither case was there any analysis to prove the assumption. The true conditions were stated by Coulomb more than a century ago.

The crushing resistance of wrought iron cannot be definitely determined, for wrought iron does not yield suddenly to such a stress. The values given in the writer's "Resistance of Materials" have a great range, some even exceeding the ordinary tensile strength of that metal. Therefore, the remark "that the crushing resistance of wrought iron is from  $\frac{1}{2}$  to  $\frac{3}{4}$  as much as its tenacity," has been omitted in the editions of that work subsequent to 1871.

## ON SCHOOLS OF FORESTRY.

By REV. J. CROUMBIE BROWN, LL.D.

Abstract of a Paper presented to the Scottish Arboricultural Society.

THE Schools of Forestry on the Continent of Europe are educational institutions, in which provision has been made for leading candidates for employment as foresters through a protracted course of study, similar to what is required in Scotland as a preparation for the so-called learned professions of law, medicine and divinity.\*

They may be considered as a necessary requirement of the system of forest management introduced on the Continent of Europe in the beginning of the present century, and also as a means of advancing the *Forst-Wissenschaft*, or Forest Science of the day, and of promoting its application to the treatment of forests, so as to secure the greatest benefit from the system of forest economy considered the best adapted to the circumstances and condition and requirements of any particular case.

Some three hundred years ago it was perceived by Sully, the distinguished

minister of Henry IV., that France was being ruined by the destruction of her forests; I almost quote his own words. And a hundred years later there was passed in 1666 a famous ordinance to regulate the exploitation of these. The evil was not confined to France, and for a hundred and fifty years, in France and elsewhere, various measures were devised and adopted with a view to averting the catastrophe; but it was found that these could at best only retard the destructive process. At length Hartig and Cotta devised what is known in Germany as the *Fachwerke methode* of forest exploitation, the aim of which is to secure simultaneously, and without prejudice to each other, a sustained production of wood and timber, a progressive amelioration of the state of the forests, and a natural reproduction of these by self-sown seed.

In India, as in France and in Germany, it was found that the forests were being

destroyed, that the destruction of these was entailing privations and sufferings upon the people, and that more disastrous consequences were looming in the distance. After careful deliberation, it was determined that a body of forest officials, educated at schools of forestry on the Continent of Europe, should be procured.

The expense was considerable, and it may be considered that this was a bold measure, but the results have justified the steps taken. By progressive amelioration of their condition, forests there have risen greatly in value and have been vastly extended, and the revenue from forests has been increased by *hundreds of thousands of pounds*. All which has been accomplished—not by an impoverishing of the forests, but by a progressive amelioration of these and an increase of their pecuniary value in something like a corresponding ratio.

In illustration of this latter allegation, I cite the following statement, made by Captain Campbell-Walker in a paper on "State Forestry: its Aim and Object," read before the Otago Institute, Dunedin, 21st December, 1876:

"The Chunga Munga plantation, in the Punjab, has an area of 7000 acres, commenced in 1865, contains chiefly Indian black-wood (*Dalbergia sissoo*). The expenditure up to end of 1873 had been £26,000, including £5,000 spent during the first five years in unsuccessful experiments; £5,000 had been received from petty thinnings (firewood and minor produce, grazing dues, etc.). From a careful valuation, and calculations made in 1873, it is estimated that the expenditure up to 1881, when the capital account closes, will be £97,000, and the value of the plantation be then £170,000. In considering the above results, it must be borne in mind that the rainfall in the district is under 15 inches, with great heat in the summer, and sharp frosts in winter. The whole plantation has to be irrigated from a neighbouring canal, being debited with a charge of 4s. per acre per annum for the use of the water alone. Another important fact must be mentioned, viz., that, whereas the land on which the plantation stands was formerly almost valueless, and would not fetch an annual

rental of 2s. per acre; 12s., and even 20s. per acre is now readily obtainable, and the former has been offered for the whole or any portion when cleared. The rents mentioned, of course, include the water-rate of 4s. per acre per annum. This plantation is intended eventually to cover 30,000 acres, and will undoubtedly prove a great success, both as regards direct financial profit, a supply of timber or firewood, which is much required, improving the soil, and rendering it fit for cultivation with cereals, and ameliorating the climate. The Nelambur teak plantations, in Madras Presidency, cover 3,000 acres, the oldest portion having been planted thirty years ago. The total expenditure, including purchase and lease of some 19,000 acres of land from a native raja, has been £30,000, and the receipts from thinnings, etc., £10,000. These plantations were valued last year at minimum rates at £150,000, and Colonel Pearson, lately officiating as Inspector-General of Forests in India, estimated their value, when mature, at no less than two millions sterling."

An examination of the programme of study will show that in most of the schools of forestry on the Continent of Europe the course of study is similar, most of the modifications being attributable to national or local conditions. It embraces, besides, matters pertaining specially to forest economy, studies which may be called preliminary or fundamental, and studies which may be called accessory or supplemental.

In the programme of study followed at Aschaffenburg, in Bavaria, which extends over two years and a half, we find that during the first summer session attention is given to Botany, Zoology, the Chemistry of Vegetation, Natural Philosophy, Mathematics, Chart Drawing, and Political Economy.

In the winter session following, instruction is given in Forest Economy, the Game Laws, Botany, Zoology, Chemistry, Mineralogy, Atonics, Hydrostatics, Pneumatics, Heat, Acoustics, Optics, Magnetism, Electricity, Meteorology, Trigonometry, Mensuration of Solids, and Plan Drawing.

In the second summer session there is continued the study of Forest Mensuration, Meteorology, Botany, Zoology,

Chemistry, Land Mensuration, and Plan Drawing.

In the second winter course attention is given to the Systematic Management of Forests, according to different objects aimed at; and the Historical Development of Forest Economy, Forest Technology and Finance, the Timber Trade, the Management of State Forests, Entomology, Organic Chemistry, Geology, Road-making, Dam-making, and Bridge-building, and practice in Forest Mensuration in its every department.

In the concluding summer session attention is given to the practical application of all previous instruction, and instruction on excursions in the whole round of forest operations, instruction in Forest Administration, in Rural Economy and Agriculture, and in all works of Forest Engineering.

Facilities for the prosecution of field and forest studies abound in the vicinity of Aschaffenburg, but the excursions take in a wider range, and extend to the Black Forest, to the forests on the Rhine, and to the pine and fir forests of France. All of these are conducted by the professors or teachers.

There may be much in such a curriculum of study as this which is not deemed requisite as training for the management of British woods and Colonial forests. On this point I have no design to raise a controversy at this stage. The position which I take up is this: The Governments of almost every country on the Continent of Europe—Denmark, Holland, Belgium, and perhaps Greece, being apparently the only exceptions—under the influence of students of forestry, have deemed it expedient to make provision for the instruction of officers in their forest service in all of the subjects embraced in that curriculum. The British Government of India have deemed it expedient to do the same, in so far as existing arrangements permit of this being done, and have found their advantage in the result; and in view of this I raise the question, May not something similar, but adapted to meet the requirements of our conditions, be done by us?

In the location of the schools of forestry on the Continent, considerable diversity exists, and the knowledge of

this may be of some importance in considering what may be done.

In some countries the schools of forestry are distinct separate institutions; in others they are connected with other educational arrangements, which in some, but not in all, are in part utilized, and, so to speak, made subservient to the education and instruction of the students of forest science.

Of these, the schools of forestry at Stockholm in Sweden, at Evois in Finland, at Lissino in Russia, at Nancy in France, at Vallombrosa in Italy, and in the Escorial in Spain, are exclusively schools of forestry. The school of forestry at St. Petersburg in Russia is located on the same grounds with a school of agriculture, but in separate buildings. Of the schools in Germany cited, those at Neustadt, Eberswalde in Prussia, and at Munden in Hanover, are exclusively such. The same may be said of that at Aschaffenburg in Bavaria, but it has just been raised to association with the University of Munich. And that at Giessen in Hesse-Darmstadt is incorporated or embodied as one of the faculties in the University of that city. At Tharand in Saxony, and Hohenheim in Wurtemberg, the schools of forestry are connected with schools of agriculture and rural economy; at Carlsruhe, in the grand duchy of Baden, the school of forestry is combined with a college of engineers in the Polytechnicum of that city.

One advantage of such combinations is, that many subjects may be studied by students of different faculties under the same teacher, as is done in the arts classes of our Scottish universities by students contemplating the study of theology, of medicine, or of law; and one staff of instructors thus suffices for the whole, with only special instructors for special subjects of study pertaining to the different professional departments, who conduct their students through these in the same sessions in which they prosecute the studies required of all. There are many advantages found to be connected with the location of a school of forestry in the vicinity of a forest, in which from time to time illustrations of what is advanced in the class-room may be found. But this is not indispensable to the successful teaching of forestry.

It may be said that one-half of the schools of forestry are not so situated, and, even in those which are, the students are taken to see actual forest operations at a distance. The students at the Laesnoi Corps, St. Petersburg, are taken to Lissino, seventy versts, or nearly fifty miles distant. Those at Nancy, in France, are taken to study forest work in the oak forests of Central France, in the coniferous forests of the Vosges and the Jura, and in the perimeters of *reboisement* and *gazonnement* on the Alps. And the students at Aschaffenburg, in Bavaria, are taken, as has been stated, to the Black Forest, to the forests on the Rhine, and to the pine and fir forests of France. I cite only cases on which I have reported, but there are others in which advantage is taken of the facilities afforded by railways for taking students to study practical forestry in districts at a great distance from the locality in which the school of forestry is situated.

It seems to me that the facility for locomotion supplied by railways, combined with the fact that the local expense of board, etc., is very much the same everywhere, has somewhat modified the views once entertained in regard to the location of a school of forestry, in, I shall not say "a cottage," but a palace, "near a wood,"—for in such some of the schools of forestry on the Continent have been located. I may be allowed to state in this connection that, on the publication of my plea for the creation of a school of forestry in connection with the proposed Arboretum, one of my correspondents, Professor Blomqvist, director of the school of forestry at Evois, in Finland, wrote to me on this point, calling my attention to views expressed at a convention of State foresters, etc., at Freiburg, where it was said to be unanimously agreed that a university was the proper place for the study of forest science.

#### REPORTS OF ENGINEERING SOCIETIES.

**ENGINEERS' CLUB OF PHILADELPHIA.**—At a meeting of the club held March 16th Mr. Rudolph Hering read a paper on "Bearing Piles," giving formulae for their sustaining power, size and disposition in any foundation. There has been much uncertainty in the minds of many practical engineers regarding the proper formula for pile driving.

Piles were divided into two classes. The first class consisting of those which are driven to a solid foundation and act as pillars or columns of support, and which are therefore designated as *columns*. The other class consists of such as derive their supporting power from the friction of the material through which they pass. These alone are properly called *piles*.

Experience has proven that quick blows with a heavy ram give greater penetration at a less expenditure of power than slow blows with a light ram. In sand or silt the blows should follow rapidly, in order to prevent the ground from settling around the pile before the next blow of the ram.

On account of the many uncertainties in connection with piles a wide margin of safety in loading them is recommended by all authorities. It is sometimes impossible to tell how much of the sustaining power is due to a solid bottom and how much to friction alone. There is often no guarantee that a pile will not steadily sink under a heavy quiescent pressure applied continuously, when it withstood perfectly a corresponding sudden blow from the ram. This is especially to be feared in clayey soils.

The vibrations of the structure may in time produce unexpected settlements; this may also occur when certain clayed soils become very wet adjoining the piles, and the friction is thereby lessened.

A table of safe loads, giving a comparison of values taken from the works of all the authorities on the subject, was exceedingly interesting, and from it the following was deduced: That all formulae, developed from purely theoretical speculation, regarding the resistance of the frictional surface of the pile in the ground, vary greatly among each other and are also unreliable for other reasons.

The only method which can be depended upon in calculating the sustaining power of piles held by friction is the experimental one, which introduces the actual distance which a pile sinks under the last blow. The formulae developed from experiment also differ very much as usually given, but when properly analyzed, classified and compared they will enable the engineer to make an intelligent selection and to obtain a perfectly satisfactory result.

Mr. William A. Ingham called the attention of the Club to some drawings, which had just been received from Europe, of "Steam Boilers and Engines for high pressures," by Mr Loftus Perkins of London. These engines are compound, having three cylinders of proportionate sizes.

In marine engines of this pattern it is customary to use nothing but fresh water in the boiler, and to use this over and over again. This is easily accomplished by thorough condensation of steam used and by avoidance of all leaks.

Mr. H. C. Lewis made some very interesting remarks on the erection of the temporary bridge at New Brunswick, over the Raritan river.

Mr. Charles E. Billin exhibited a new form

of tripod for transit and level instruments, which is being manufactured by Messrs. Heller & Brightly, of Philadelphia. The instrument is a combination of the ball and socket motion and the four leveling screws. By its use fully two-thirds of the time necessary in field operations is saved, as the instrument can be set up and approximately leveled in an instant without the use of the leveling screws. The various parts of the instrument were described, and it was stated that any make of instruments can be altered to this greatly improved form at a very small cost.

At a meeting of the Club, held April 6th, Mr. D. McN. Stauffer made some remarks concerning recent developments relative to the South Street Bridge. Borings had been made about 20 feet distant from each end of the pier which caused the fall of the structure. At the south end, which did *not* sink, gneissic rock was found 37 feet below the surface of the marsh. The rock was overlaid by 18 to 20 inches of gravel, and then a considerable thickness of a hard, very compact yellowish clay.

At the North end, which failed by sinking, the same gneissic rock is 33' 8" below the surface. On top of the rock is 3' 8" of black mud and above this about 7' of gravel. This tongue of mud running under the North end of the pier was doubtless the cause of the trouble.

The piles were driven nearly through the gravel stratum, friction of the material resisting further driving. Lubrication of the piles by the slow percolation of water, aided by the vibration of the structure produced by travel on the bridge, destroyed this frictional value, and threw additional weight on the toe of the piles. Supposing this to have been the case, with a yielding material under the gravel stratum, sinking was inevitable.

Prof. L. M. Haupt read a paper "On the proposed removal of Smith's Island." This is a question affecting directly a large number of the industries of this city. The commercial interests of Philadelphia have developed to such an extent as to create a demand for greater wharfage facilities with deeper water; and that cereals and merchandise may be delivered without too many handlings, it is desirable that cars should be run immediately alongside the vessels to be laden. To accomplish this it is proposed to lay tracks on Delaware Avenue, already too narrow, and to make provision for the space thus occupied by extending the Port Warden's line further out, which will contract the channel, now only about 800 feet wide in its narrowest part. Some of our largest shippers have requested permission to extend their wharves several hundred feet. Were this done in a few isolated cases, it would introduce dangerous barriers to navigation, and if an advance were made all along the line it would seriously contract the channel, unless a portion of Smith's Island were removed.

To widen the channel to 1,000 feet, along the Smith's Island front and to a depth of 18 feet, would require the removal of 5,000,000 cubic yards of material at a cost of about \$1,000,000.

The same depth and width of channel may

be obtained, if desired, for less than one-tenth the cost of dredging, by a careful adjustment of the *regimen* of the river by auxiliary constructions, such as jetties, rip-raps, sand-fences, or bottom-dams.

A comparison of all the maps and records, shows an average movement of the lower end of the Island up stream from Christian Street to South Street, a distance of 1,900 feet in 106 years, or from 1762 to 1868.

**SOCIETY OF ENGINEERS.**—At a meeting of the Society of Engineers, held on Monday evening, March 4th, in the Society's Hall, Victoria-street, Westminster, a paper was read by Mr. J. Walter Pearce, on "Water Purification, Sanitary and Industrial." In his opening remarks, the author observed that, until the metropolis was furnished with a supply of water from pure sources, private filtration was necessary, and chemical purification was required, as well as mere mechanical filtration. Great diversity of opinion existed as to the value of the various substances used as purifying media, and also as to the form of filter. The first record of a water filter was in 1790, when Johanna Hempel employed porous vessels; and in the following year the ascending principle was first mentioned. Vegetable charcoal as a filtering medium was first named in 1802, animal charcoal in 1818, and solid blocks in 1834. Turning to the modern practice of filtration, the author observed that Atkin's system embodied the last-named principle, finely divided charcoal being agglomerated into porous blocks. The advantage of employing carbon in that form was that the impurities were arrested on the surface, and were easily removed. Major Crease, R.M.A., compressed loose animal charcoal in a granular state, between plates, by means of a screw, the amount of compression being determined by the degree of impurity in the water to be filtered. Major Crease's system is adopted in the Army and Royal Navy. The chief characteristic of Mr. F. H. Danchell's filter was that the ascending principle was used, so that impurities, instead of lodging on the top, fell back on to the bottom of the tank. The Sanitary Engineering and Ventilation Company use mineral carbon as a filtering medium, and cause their cistern filter to be cleansed by the inrush of the supply, and also by reversing the flow. In the Silicated Carbon Filter, mineral charcoal is used as the filtering medium, the main supply filter having three slabs with layers of coarse and fine granular carbon between. In Professor Bischoff's spongy iron filter, the iron exerts a powerful influence on the water, impregnating it with iron, which is afterwards oxidized and arrested, leaving the water pure.

M. Le Tellier's hydrotrimetric purifier was described as removing the hardness from water by throwing down the lime, which was afterwards intercepted by filtration through charcoal. A jet of lime water is made to mingle with the stream from the supply pipe, and the precipitated lime is afterwards arrested by filtration. M. Le Tellier has also invented a high-pressure apparatus on the same principle,

for dealing with large bodies of water used in manufacturing processes, and for purifying the feed water of steam boilers above twenty horse-power. On the same bed-plate are fixed two close vessels, the smaller containing the lime water or other re-agent, and the larger, the mechanical filter for arresting the precipitate, the two vessels being connected by an injector. The supply, which must have a pressure due to a column of at least ten feet in height, enters by an inlet pipe, and most of it passes through the injector into the filtering chambers. A portion, however, descends another pipe, and issues through perforations at its lower end, keeping a disc, which is supported by a spiral spring, in a state of continual trepidation, and thus assisting the combination of the water with the re-agent, previously inserted. The rush of the main supply through the injector draws along with it the lime water from a small pipe, and the two pass together into a vertical tube, which is traversed by pins set alternately at right angles to each other, for bringing about a more intimate union. A valve also admits atmospheric air for aiding in the process. Arrived at the filtering chamber, the lime is thrown down to be removed periodically through a cleaning pipe, and the pure water passes through the filter tubes into the purified water reservoir below, whence it is drawn through a pipe by a pump or injector in connection with the engine and the boiler.

The filter proper consists of wrought iron tubes, perforated with holes, and covered by discs of felt which are compressed between cast iron plates screwed up with a gun-metal nut. The lower ends of the tubes are conical, and fit into sockets screwed into the plates which separate the unfiltered water chamber from the filtered. The number of the tubes varies with the size of the apparatus; but the filtering area of each tube is very large in comparison with the space it occupies, being equal to the height multiplied by its circumference. Each tube may be lifted out of its socket for cleaning or replacing. A cleansing of the whole apparatus is also effected by turning steam into the outlet pipe, which heats the water in the lower chamber and forces it through the tubes and felt, expelling any impurities which may have collected there, to be washed away by rinsing with clean cold water. This apparatus is largely employed by manufacturers on the Continent; and when used for potable water a second filtering medium of vegetable charcoal is added. Mr. A. Durand Claye, director of the laboratory of the Ecole des Ponts et Chaussées, Paris, made some experiments with the Le Tellier filter purifier in 1875, and found that water of 24° of hardness was reduced to 5° after passing through the apparatus, while the solid residue was reduced from 3.31 grammes to 0.92 gramme, a gramme being equal to 15 grains. The reading of the paper was followed by a discussion, after which the following gentlemen were balloted for and duly elected:—viz., as members, Mr. Thomas Andrews, Mr. Christopher George Search, Mr. Francis Brickwell and Mr. James Cleminson. As associates, Mr. John Joyce and Mr. Joseph Samuel Beeman.

**INSTITUTION OF CIVIL ENGINEERS.**—At the meeting on Tuesday, the 26th of February, the paper read was on "Liquid Fuels," by Mr. H. Aydon.

It was stated that apparatus specifically adapted for the combustion of liquid fuels, which comprised every class of fluid hydrocarbons, might be ranged in five classes. The leading principle of their action was either the subdivision of the liquid as spray, or by percolation through a porous bed, or by preliminary conversion into vapor—when the fuel was mixed with air, or with air and steam, by the instrumentality of jets of steam or of compressed air, or it was burned simply as gas in jets.

The results of the use of liquid fuel in Russia and other foreign countries were given in the paper, together with the conclusions of Mr. Isherwood, Chief Engineer of the U.S. Navy, on its employment in steamers.

The author made the general deduction that, although liquid fuel might be burned without the employment of steam, yet it was consumed most economically, and with the best results, in the presence of steam; and, of course, the more highly superheated the steam, the better was the performance.

At the meeting on Tuesday, the 5th of March, Mr. Bateman, president, in the chair, the paper read was "On the Hooghly Floating Bridge," by Mr. Bradford Leslie, M. Inst. C.E. This bridge connected Calcutta on the left with Howrah on the right bank of the Hooghly, at a short distance north of the East Indian Railway terminus.

Of the publications of the Institution we have lately received Doherty on Coffey Dams, used at Dublin, Birkenhead and Hull; also Part 1 of Vol. LI of Abstracts of Foreign Transactions and Periodicals.

## IRON AND STEEL NOTES.

**FRENCH IRON TRADE STATISTICS.**—The official returns of the French iron trade have just been issued, and set forth a number of details which are worthy of notice. On the whole, the industry would seem like our own—to have suffered from depression during the year—but the totals are in several respects very respectable as to size, and, at all events, tend to show that our Gallic neighbors are making considerable progress in this important branch of metallurgy. The total quantity of iron and steel exported from France during the twelve months ending December 31st, 1877, was 169,204 tons only, as compared with 206,248 tons in 1876, or a falling off equivalent to about 17 per cent. The quantity of mineral ore sent out of the country also diminished most materially, for only 79,112 tons were so dealt with in 1877, as against 105,190 tons in 1876. Of this raw material 47,216 tons only went to Belgium against 60,212 tons in the previous year, and 30,104 tons to Germany, as compared with 42,728. On the other hand the mineral ores imported into France reached the total of 975,630 tons as against 849,186 tons in 1876. Of the former aggregate 330,049 tons came from Algeria, 248,226 tons from

Spain, 223,443 tons from Belgium, 139,775 tons from Italy, 30,700 tons from Germany, and 3425 tons only from Great Britain and all other countries. During last year, too, the quantity of cast iron articles imported into France was 212,896 tons, as against 184,344 tons in 1876; of wrought iron, 62,735 tons against 56,385 tons; and of steel, 5009 tons, as compared with 5445 tons in 1876. From the statistics it will be pretty clear that in no sense of the word can France yet be deemed a formidable competitor of our iron manufacturers, for her own exports have not only diminished, but she has also been compelled to use a considerably greater quantity of foreign iron. Her total exports of iron cannot be compared with those of Great Britain, for the whole year's foreign shipments of such articles only amount to about the same as those of this country for a single month. At the same time it would be very unwise to lose sight of the fact that the French are progressing very rapidly in industrial matters, and may presently become "foemen worthy of our steel," or to export their own. —*Engineer*.

#### RAILWAY NOTES.

THE average locomotive mileage per year in the different countries of the world has been calculated by Prof. Stuermer, of Bromburg, and for the leading countries the figures are given in the *Railroad Gazette* as follows:—France (1873), 23,475 miles; United States (1875), 21,900; Great Britain (1875), 16,865; Germany (1875), 11,834; Austria (1875), 11,700 all Europe (1875) 15,300; East Indies, 13,400. From the same source we learn that the average number of trains per day both ways in 1875 was 20.9 in Europe, 14.7 in the United States, and 8.2 in India.

THE *Lafayette (Ind) Journal* of December 18th says:—We have often noticed fast time being made on the Wabash Railway, since the putting on of their fast trains, but it was left for No. 4 on last Saturday to beat anything ever done between Lafayette and Toledo. In consequence of the engine breaking down between Danville and Lafayette, the train was over one hour late leaving here, but went into Toledo on time. Engine No. 20—Chapman engineer—took the train to Fort Wayne in two hours and forty-two minutes—the quickest time ever made between Lafayette and Fort Wayne: and from the latter place, engine No. 46—Humphrey, engineer—to Toledo, accomplishing the whole distance of 203 miles in four hours and forty-two minutes. Allowing time for stops, experts claim the distance was run in four hours, which is fully fifty miles per hour. This time has never been equaled in this country by a regular train with no preparation more than usual and making all regular stops.

FOLLOWING is the latest railroad news from Colombia, S. A.: Work on the Antioquia Railway is progressing favorably. With 125 men 2900 feet was laid in August. The contractor now proposes to put 500 men on as soon as he can get them. Mr. Ross has a

contract for the construction of the "Central Railway" at a cost of \$20,000,000. He is to receive a subsidy of \$250,000 a year for twenty-two years, and 25 per cent. of the product of the customs. The general direction of the Central Railway will be from a point on the west bank on the Magdalena, below the mouth of the Sogamosa, or in the Cienega de Paturia, and will proceed *via* the Lebrija river to Bucaramanga, and thence through Piedecuesta and Somjil to Bogota, passing as near as possible to the larger towns in the States of Santander, Boyaca and Cundimarca. The contractor will be allowed twelve years to complete the railway, allowance being made for any stoppage of the works for which the contractor is not responsible.

THE annual reports of the condition of railways in Great Britain for 1876 afford some interesting points of comparison with roads of the United States, and the following is made by *Engineering News*:—There are only 16,872 miles of railway in Great Britain, the addition for 1-76 having been 214 miles. The number of miles of road in the United States is 77,000—more than four times the number of miles in Great Britain. In the latter country there is one mile of road to every 2,000 persons. In this country there is one mile of road to every 533 persons. The first reflective suggestion by this is that Great Britain is very insufficiently supplied, and the United States very well supplied with railways. But there are other facts in the comparison which show that Great Britain possesses nearly all the railways it needs, while we possess more than can be run at a profit, and therefore, more than we really need. The total nominal capital of the 16,872 miles of British railways, including stocks and loans, is \$3,290,000,000, while the total nominal capital of our 77,000 miles is about \$4,500,000,000. The capital of British railways represents an average cost of about \$190,000 per mile, while that of our railways represents an average cost of about \$53,000 per mile. The gross earnings of the British roads for 1876 were \$310,000,000, or \$18,440 per mile, and the net earnings on our roads were \$497,000,000 or about \$6600 per mile, and the net earnings \$186,000,000 or \$2415 per mile. Our 77,000 miles of road earned more than a half more, gross, than the 16,872 miles of British, but the net earnings of the British roads were nearly four times as great to the mile as ours. The percentage of operating expenses in Great Britain is 54 per cent, of the gross earnings; in the United States it is 69 per cent.

#### ENGINEERING STRUCTURES.

THE HOOGHLY FLOATING BRIDGE.—At a late meeting of the Institution of Civil Engineers, Mr. Bateman, president, in the chair, the paper read was on "The Hooghly Floating Bridge," by Mr. Bradford Leslie, M. Inst. C.E.

This bridge connected Calcutta on the left with Howrah on the right bank of the Hooghly, at a short distance north of the East Indian Railway terminus. Various projects had been

from time to time proposed, but ultimately the preference was given to a floating bridge, as it could be more cheaply and expeditiously constructed than a fixed bridge. The design was prepared in 1868, when it was intended to be carried out by a joint-stock company, but after much delay, in 1872 it was undertaken through the agency of the Local Government of Bengal. The work was commenced in January, 1873, and the bridge was opened for traffic in October, 1874.

The present structure was the first, and, up to this date, the only one of its kind affording headway for river navigation. It divided the port into two sections. The lower part was occupied by sea-going ships and steamers, and the upper part by inland craft and a few coasting vessels. As, however, the graving docks were above bridge, it was necessary that an opening should be provided for the passage of shipping. The extreme rise and fall of the tide during floods was twenty feet, and at certain seasons there was a tidal wave six feet in height. The maximum velocity of the stream was six miles an hour. The depth of the river at the site of the bridge was variable, the greatest depth at low water being six fathoms.

The bridge was 1530 feet long between the abutments, and the roadway was forty-eight feet wide, with footpaths each seven feet in width on both sides, so that the total width of the platform was sixty-two feet. There were four main longitudinal wrought-iron girders at intervals of sixteen feet in the width of the roadway, raised by timber trusses, resting upon pontoons, to a convenient height above the water for accommodating the boat navigation. The platform of the bridge was level for a distance of 384 feet on each side of the center, at a height of twenty-seven feet above the water. Thence it fell by inclines of one in forty to a distance of 584 feet on each side of the center line, where there was a length of twenty feet of level platform twenty-two feet above the water. Between these points and the abutments were the adjusting ways, the shore ends of which were thirty-two feet above low water. The approach on the adjusting ways was by a descent of one in sixteen at extreme low water, and by a corresponding ascent at extreme high water; but at ordinary times it was either level, or only slightly inclined. The platforms of the adjusting ways were supported on the lower flanges of three bow-string girders, the roadway being divided into two by the center girder. The footpaths were carried on cantilevers riveted to the outer girders. The bow-string girders weighed sixty-six tons each. They were 160 feet long between the end pins on which they were hinged, and had the usual trough-shaped upper and lower members. The shore ends of the bow-string girders were suspended on links, which was preferable to carrying them on rollers, even for fixed bridges, as being less likely to get out of adjustment, and tending always to restore the girders to its normal position at its mean temperature. The outer floating ends were hinged to pivot bearings, in order to admit of a slight drift up and down stream.

The floating portion of the bridge was carried

on twenty-eight pontoons, coupled together in pairs to secure stability. With the exception of the two pairs in the center, which supported the movable sections of the bridge, each pair carried 100 feet in length of the platform. Each pair was coupled together, at a maximum distance of forty-one feet from center to center, by four timber cills, bolted to the decks of the pontoons at intervals of sixteen feet. These cills constituted the bottom members of the four main longitudinal trusses, the top members being the wrought-iron girders carrying the roadway. With the exception of the upper girders, the whole of these trusses were of teak. The coupled pontoons were further connected by strong horizontal diagonal bracing of bar iron. The timber cills and the bracing being only four feet above the water, the space between the coupled pontoons was not available for navigation, and floating fenders or booms were provided to divert boats from these openings. Ordinarily the main girders overhung the pontoons twenty-one feet, their ends being supported by the inclined struts of the trusses, leaving a width for navigation of forty-two feet, partially obstructed by the raking struts. For the convenience of the country craft, there were two rectangular openings of sixty feet clear span between the fourth and the fifth pairs of pontoons, reckoning from each abutment. The roadway over these openings was carried on eight girders, each  $2\frac{3}{4}$  feet deep, and weighing eight tons. They rested on saddles secured to the top of the cross-bearing girders, which were suspended to the ends of the ordinary main truss girders. All the pontoons were 160 feet long, by ten feet beam, with holds varying from eight to eleven feet in depth, according to the dead weight to be carried. Each pontoon, excepting those of the movable sections, was accurately anchored by permanent moorings, laid exactly in line with the center of the pontoon, the distance between the up and the down stream anchors being 900 feet. The strain on the chain cables varied from five to twenty-five tons; their great length afforded the necessary "spring," to allow for the rise and fall of the tide, but a few links were taken in during the dry season, and slacked out again during the flood season.

The 200-feet opening for the passage of ships was one of the most difficult problems in designing the bridge. Owing to the strength and irregular set of the stream and eddies, ships could only be moved at or near slack tide; and it was a rule that all vessels of more than 200 tons must be moved by steam against the tide. The bridge was generally opened twice a week at high water, but occasionally at low water. The opening was effected by removing the two center sections of the bridge bodily. These sections were connected with the fixed portions of the bridge by draw-bridges, which, on being run back, left a clearance of twenty feet on each side of the platform of the movable sections. By means of steel warps, laid to buoys moored for the purpose, these sections were warped up stream far enough to clear the rest of the bridge. They were then disconnected and sheared over, one on each side, leaving a fair way clear of all obstructions.

The bridge was closed by reversing these proceedings. The ordinary time taken in opening the bridge was fifteen minutes, and in closing it twenty minutes.

There was a daily traffic of about 6000 tons of heavy goods, which were conveyed in bullock carts, besides foot and carriage passengers. The iron work of the pontoons weighed 1650 tons, that of the girders 875 tons. The whole of this, as well as the mooring chains, was sent from England, and was erected and riveted up in Calcutta. The teak timber, which weighed 1500 tons, was procured from Burmah.

The different parts of the structure were minutely described. An account was also given of the operations connected with the laying of the forty-eight permanent moorings, with the fitting of the truss-work, with the hoisting into position of the sixteen sixty-foot girders, and with the erection and launching of the 160-foot bow-string girders. The particulars were likewise recorded of an accident that delayed the completion of the work about three months. This arose from a deeply-laden ship fouling two vessels, which parted from their moorings, and both were sent up stream on the top of the "bore" at the rate of five knots on hour. One vessel went through the center opening, but the other struck the bridge, causing three pontoons to be sunk, and the superstructure to be completely wrecked.

**A MONSTER MINE ENGINE.**—A piece of machinery that has given employment for several months to about 500 skilled artisans, has been completed at the Union Ironworks, at a cost of \$300,000. This great expenditure of labor and money has embodiment in the largest engine ever constructed on this coast. Technically described, the engine is a horizontal, low-pressure, compound, condensing, of 1500 horse-power. With boilers, pumps and gear it aggregates a weight of 1200 tons. One of the cylinders is so heavy that a special car will have to be constructed to transport it to its destination—the Yellow Jacket Mine—where a shaft is being sunk to a depth of about 2300 feet to strike the Comstock. The engine is to be used at this shaft for pumping. It is now being put together at the foundry preparatory to shipment. This engine rests on a horizontal base, 64 feet in length, each side of which is cast in three pieces for convenience of shipment. The breadth of the engine is 18 feet. The power is communicated from the two cylinders to a forged cross-head, to which is attached the shaft connecting with the **v** bob working the pumps. The cross-head is the largest piece of iron ever forged in San Francisco. It weighs 22,000 pounds, is 21 feet in length, 9 inches in thickness one way and 3 feet the other. The shaft and crank weigh 26 tons. On each side of the engine, about half way between the cross-head and the connection of the shaft with the **v** bob, is a flywheel 30 feet in diameter and weighing 30 tons. These flywheels are connected by a shaft 18 inches in diameter, running through the main shaft. The cylinders consist of an initial cylinder 32 inches in diameter, weighing 12 tons, and an expansion cylinder 65

inches in diameter, weighing 30 tons. The pistons of these cylinders have a 12-foot stroke. They carry steam pressure of 130 pounds, expanded eightfold. The cylinders and cylinder heads are steam-jacketed, being covered with a thick coating of asbestos, a non-conductor of heat. The engine is supplied with an air-pump of the most improved construction, fitted with an automatic injection-valve, and is operated with O'Neil's cut-off valve motion. Every modern mechanical appliance has been embodied in this engine, and every part which will be subjected to wear has been case hardened. During the progress of the work several costly machines were constructed which were necessary to make parts of the engine. The proprietors of the works, Messrs. Prescott, Scott & Co., have taken more than ordinary pride in the execution of the contract, refraining in every particular from incorporating in the machinery any part not strictly of San Francisco. This has been done in the interest of home industry, which had some weight with the Bonanza firm when they awarded the contract, this firm being the principal holder of Yellow Jacket stock. This firm is demonstrating the feasibility of manufacturing all classes of engines in this city, and they entertain the opinion that it will not be many years before the importation of engines and pumps from the East will be done away with altogether.

There are two massive bronze plates fixed on each side of the base castings of the engine. One of these is emblematic of the industry to which the machinery is devoted. In the center is the figure of a miner at work in the drift, and surrounding it are surface scenes on the Comstock. The other plate bears the following inscriptions:—"Yellow Jacket Mining Company, T. G. Taylor, superintendent; William H. Patton, construction engineer; Prescott, Scott & Co., builders 1878." The letter "S" in the left-hand lower corner, and the letter "F" in the right-hand lower corner.

The new shaft of the Yellow Jacket Company, in which the machinery is to be placed is estimated to cost \$1,000,200. This figure covers the cost of the machinery. The shaft is now down about 1600 feet, and to push the work to completion it will be raised from the 2200-foot level. The 2200-foot level is represented to be only 40 feet from the line of the shaft. When the connection is completed, all the drainage of the mine will be carried through it. The machinery has sufficient capacity to carry the working to a depth of 3000 feet.—*San Francisco Mining and Scientific Press.*

## ORDNANCE AND NAVAL.

**A NEW TWIN STEAMER.**—The trial trip of the new twin steamer *Express* which has been built by Messrs. A. Leslie & Co., shipbuilders, Hebburn-on-Tyne, for the Channel Passage Company, for service between Dover and Calais took place recently. The passage between Dover and Calais is a very turbulent, and therefore an uncomfortable one for passengers; and the question how to make the voyage lighter and steadier, so as to remove the

discomfort attending it, has often presented itself to nautical minds. Some few years ago Captain Dicey, the originator of the Channel Company, designed the *Castalia* for this object and, so far as equability and comfort were concerned, she thoroughly answered her purpose; but her speed was so far below that of ordinary steamers and, therefore, although many preferred the more pleasant passage and chose to take the slower vessel, the majority elected rather to face the storm and have the advantages of the swifter mode of transit. Mr. Leslie, however, undertook to produce a vessel having the qualities required, and the result has been the *Express*. She is a sister ship to the *Castalia*. The *Castalia* has something like 1100 horse-power. When it was made patent that that vessel had not enough engine power to enable her to compete successfully with the Dover and Calais mail boats, Mr. Leslie and Mr. Parkes experimented on the Thames with two Woolwich paddle boats locked together, and from these experiments, combined with the data gathered from the trials of the *Castalia* they established the base for calculations for building a new boat to attain double her speed. The difficulty in the way of designing a new ship of the dimensions of the *Castalia* with the same draught of water, 7 feet, but with a propelling power of 4000 horses as compared with 1100 horse-power, was considerable. The extra displacement, however, was obtained by forming the inside lines of the two ships elliptical, and making the rudder form a part of the body of the ship. The *Express* was guaranteed to have a draught of no more than 7 feet, and to be capable of working at a minimum speed of 14 knots—the difficulty of this being to get sufficient power into her without immersing her too much in the water, and this Mr. Leslie has accomplished. The draught of the *Express* is about 1 foot less than the *Castalia*, her length 10 feet greater, and she is 1 foot broader. The two hulls are each about 1 foot wider, and the channel between the two ships is slightly narrower in the *Express* than in the *Castalia*; the great difference in construction between the two vessels, so far as the hulls are concerned, however, is, that whereas the *Castalia* is, as it were, two half ships placed a certain distance apart, forming between them a channel, the sides of which are parallel the *Express* is two complete symmetrical ships, thus making the channel wider towards the ends of the vessel, and narrower towards the paddle wheels. This has the result of giving a more plentiful supply of water to the wheels, and enables them to utilize a much greater proportion of power than with the parallel channel. In the *Express* the two hulls are very rigidly united together by four transverse iron girder bulkheads spanning across the channel. The rudders, of which there are four, one at each end of each ship, act also as bows without any resistance. The vessel is steered by steam, the steering gear being supplied by Messrs. Brotherhood & Hardingham, London. The whole of the passenger accommodation is provided on the superstructure. The saloons are all approached by circular staircases from the

upper decks; a large general saloon and a ladies' saloon are forward and the refreshment saloon and range of state rooms for private families aft. The furnishing is all of the highest order. The vessel accommodates 1000 passengers. The engines which have been supplied by Messrs. Black, Hawshore & Co., Gateshead, are 4000 indicated horse power. They are diagonal inclined engines, having two cylinders in each ship working on one crank pin. The cylinders are 63 inches in diameter, with 6 feet stroke and 40 revolutions per minute. There are two patent leather paddle wheels working independently of each other. The trial trip on Saturday extended along the coast to Coquet Island, a distance from the Tyne of 22½ miles. The vessel sailed remarkably steady, and a very pleasant day was spent by the Company on board. The runs from Coquet Island back to the Tyne were made a test and the distance was done in one hour and twenty-two minutes, an average of 14.48 knots per hour. The distance from the Tyne to Coquet is one mile and a half longer than from Dover to Calais. The trial was considered highly satisfactory. The *Express* is expected to commence the Channel service next month, but at all events will start in time for the Paris Exhibition.

**BREECH-LOADING ARTILLERY.**—Mr. Krupp, the inventor of the celebrated German siege gun, has been induced, by the discussion which took place in the House of Commons, on the 12th of March, relative to the comparative merits of muzzle and breech-loading artillery, to indite a letter setting forth his views, which appeared in *The Times*. Having premised that the statements made by Lord E. Cecil might lead to an erroneous impression, if allowed to pass unanswered, the writer says that England alone of European nations remains the champion of the muzzle-loader, and then argues that the failure of the English breech-loader is not proof that the principle is not good, or that the system is not susceptible of improvement. As to the German guns said to have become unserviceable during the Franco-German war, he says: "I have authentic information in reference to these guns, and all of them were, indeed, serviceable during the whole of the war, and only required some slight repairs afterwards, with the exception of four or five guns. The guns in question were a part of a number supplied to Prussia, and were constructed with copper expanding ring in the square double edge. They suffered from the escape of gas, caused principally by the double wedge slightly giving way, but none of them burst. The Saxon artillery had the steel centring ring in bore of gun and solid single wedge, and not one of these guns failed. The experience then gained has led to the perfection of the gun in detail, so that, after the conclusion of the war, the German Government remodeled the whole of its field and siege breech-loading artillery. It is also stated that the bursting of my gun on trial is not infrequent. Since the commencement of manufacturing steel ordnance in 1847 to the present date, I have supplied upwards of 17,000 guns of all

calibres, and of these only eighteen have failed, or averaging one gun in 948. By far the larger part of these eighteen failures occurred through the breaking away of the breech, owing to its then rectangular form, a form that has since been altered to the semi-circular, and not a single mishap has occurred since at this part of the gun." Alluding to the statement made that the Krupp guns used by the Turks in the recent war had to be sponged out with soap and water after each round, he contends that the fouling was due not to the build of the cannon, but to the quality of the powder, and in support of his position asserts, that with guns made by him recently fifty rounds and upwards can be fired without sponging. He then denies that the rate of firing with his gun is only one round in five minutes, and claims that at recent experiments conducted by Belgian officers the average rate was twenty five rounds in twelve minutes, with the gun laid and sighted at each round. Mr. Krupp's belief in the superiority of his gun over the English, he claims, is based on experience. When speaking on this head, he says: "Recently (August 21st, 1877) my views of the superiority of my gun over the English system have been confirmed by trials between a 17 cm. (6 $\frac{3}{4}$  inch) gun of my construction, made in Holland, against an English 9-inch muzzle-loading gun, and notwithstanding the great difference in size of the guns my 17 cm. gun proved itself of greater power in piercing armor plates than its larger opponent upon the muzzle-loading system, and also in other characteristics that give value to a gun, such as accuracy of aim, &c. The guns were fired with the same class of powder and at the same shield." The letter also contains an explanation of the statement that a proposition was made to the English Government by Mr. Krupp to lend one of his guns for £15,000, upon condition that, if it should be adopted, an order for £2,000,000 of guns should be given him. In brief, he thinks that his requirements are warranted by the costly experiments, &c., he has had to conduct, without aid from any Government. The letter terminates with this business-like sentence: "I have expressed to the English Government, and again express to it, that I have every desire to place my system at their disposal, and to enter into competitive trials; but they must be on such terms that my interests shall have equal consideration with those of the English Government."

### BOOK NOTICES.

**GENERAL REPORT ON THE PROVINCE OF KORDOFAN.** By Major H. G. PROUT. Cairo: War Office.

In December, 1874, an expedition of reconnaissance left Cairo under the command of Colonel Colston of the Egyptian General Staff, with orders to ascend the Nile in boats as far as Wady Halfa, and then proceed, by land along the left bank of the Nile, to Debbé, whence reconnaissance was to be made, first, of Wady Massoul (or Matoul), and, afterwards, of one of the routes from Debbé to El-Obeiyad.

Colonel Colston had under his orders, Lieut. Colonel Reed, of the General Staff, as second in command, five junior Officers of the Staff, a naturalist (Dr. Pfund), an Army Surgeon, a squad of Staff-Soldiers, a section of Artillery and a platoon of Infantry.

The expedition was expected to arrive at El-Obeiyad, capital of Kordofan, at least one month before the commencement of the rainy season of 1875, and, after a short rest there; was to proceed to Darfour, and there co-operate with the Staff exhibition under Colonel Purdy for the rapid reconnaissance of that country and for subsequent explorations further south in Central Africa.

Before the arrival of the party at Dongola, Colonel Colston became satisfied that his second in command, Lieut. Colonel Reed, would not be able to bear the fatigues of such an expedition, and he therefore ordered that officer to return to Cairo, and applied to the Chief of the General Staff for another field officer.

On the 2nd of February 1875, Major Prout, who was then serving as Chief of the 3rd Section of the General Staff Bureau, in the War Office at Cairo, was designated as successor to Lieut. Colonel Reed; and was ordered to proceed, by the way of Suez, Suakin, Berber and Khartoon, to join Colonel Colston.

The orders, letters, reports, maps and telegrams which appear in the appendix set forth clearly the route followed by Major Prout, the valuable work preformed by him during the journey, the circumstances under which he joined Colonel Colston, and those under which the responsibilities of the command of the expedition fell upon him.

The report on Kordofan itself, with the map of the Province and the conscientious appendices, the route-maps and special reports, evidence how much can be done by an able, instructed and honest-minded officer, in those regions, in one year, when that officer thinks less of the risks and discomforts around him, than of the accomplishment of duty for duty's sake.

The account is briefly but pleasantly given and is a valuable addition to our knowledge of this region. The maps are good and the sketches are sufficient for the purpose designed.

**ÉTUDE SUR LES MACHINES COMPOUND.** Par A. DE FREMINVILLE. Paris: Arthur Bertrand. For sale by D. Van Nostrand. Price \$1.80.

This is a prize essay on Compound Engines, prepared for the French Academy of Sciences. The subject is treated analytically and exhaustively.

The illustrations are expansion curves only, to the number of twenty.

The book is a quarto pamphlet of fifty-nine pages.

**TRAITE D'ASTRONOMIE ET DE METEOROLOGIE APPLIQUEES A LA NAVIGATION.** Par G. CHABIRAND ET L. BRAULT. Paris: Bertrand. Second Volume. For sale by D. Van Nostrand. Price \$4.00.

This voluminous treatise contains all that the ordinary student of navigation needs to know, and something more. The demonstra-

tions are expanded so as to be perfectly clear to the student of ordinary mathematical capacity, who, from necessity, works without aid from an instructor. This is the acknowledged merit of French scientific works. Everything relating to navigation is treated with equal fullness.

**ROCK BLASTING.** By GEO. G. ANDRE, F.G.S. London. 1878. For sale by D. Van Nostrand. Price \$4 25.

The use of new explosives in blasting rocks, and the widely extending use of the machine drill for boring, called for many changes in the labor methods adopted in quarrying, tunneling, etc.

The present treatise is a well printed and well illustrated volume of 200 pages, containing chapters on: Tools and Machines for Rock-Blasting; Explosive Agents; Principles of Rock-Blasting; The Operations as pursued in Quarries and Tunnels; Blasting under Water.

The Author is well known by his previous works, Coal Mining and Mining Machinery.

**TREATISE ON CHEMISTRY.** By H. E. ROSCOE, F.R.S. and C. SCHOOLHEIMER, F.R.S. Vol. I. For sale by D. Van Nostrand. Price \$5.00.

This fine octavo of 760 pages is devoted exclusively to the Chemistry of the non-metallic elements. When we consider the eminence of the authors, the space devoted to this portion alone of the entire subject, and the fact that it is only just completed, we feel justified in asserting, that no other work can compare with it in accuracy or completeness. It may be necessary to add, that no space is devoted to chemical technology, and only just enough to chemical philosophy; it is simply a complete treatise on general chemistry that any student may read with satisfaction.

**REMUNERATIVE RAILWAYS FOR NEW COUNTRIES.** By RICHARD C. RAPIER. London. 1878. For sale by D. Van Nostrand. Price \$6.00.

This book professing to aid in making estimates for railways in new countries, is but little more than an overgrown, illustrated catalogue with gilt edges.

A very little information is spread over a large amount of paper. For example: to represent six different cross sections of railway rails with their fish plates, six quarto pages are employed, and as most of the machinery represented is on a similar scale, we conclude that the main object of the author is to advertise the wares of Ransome & Rapier, whose names are conspicuous in many places throughout the volume.

**TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.** Vol. V. Easton: Published by the Institute.

This new volume includes the Proceedings of Meetings from May 1876 to February 1877, and a general index of all the published volumes. The value of these papers to the mining engineers everywhere is sufficiently attested by the fact that most of the papers have been republished in the scientific journals of Europe.

Notwithstanding the fact that mining inter-

ests have suffered in the general depression of business, the transactions of the Institute are in no sense less interesting or important than in former years.

The present issue contains 630 pages exclusive of the general index and eleven folding plates.

### MISCELLANEOUS.

**T**HE total power of all the steam engines existing in France according to recent official statistics, is 1,500,000 horse-power, representing the actual labor of 4,500,000 horses, or 31,590,000 men. This last aggregate is equal to ten times the present industrial population, which amounts to 8,400,000 souls, but from which must be subtracted old people, women, and children, leaving a remainder of 3,200,000 working men. *La Nature* compares the above data with the similar statistics of 1788, before steam engines were introduced in France, and illustrates the revolution which steam and improved machinery have produced. Ninety years ago, in every £40,000,000 worth of French products, 60 per cent. of the value represented labor and 40 per cent. raw material. To-day this ratio is exactly reversed, although labor has increased 40 per cent. At the present time the total industrial productions of France aggregates a value of about £480,000,000. Of this £280,000,000 represents raw material and the remainder labor. If the same proportion as existed in 1788 applied now taking into account the increase in labor noted above, less than eleven-twelfths of the above amount, or £440,000,000 would be the cost of handiwork. Roughly, then, steam engines and improved tools have produced an economy of £240,000,000; but, more than this, if they were suddenly swept out of existence and forgotten, there are not enough men and animals in the country to supply an equivalent amount of power, and even if there were there would be no way of procuring the necessary food for their support.

**O**n the 11th inst. Captain F. J. Evans, Hydrographer to the Admiralty, read a paper before the Geographical Society "On the Distribution of the Earth's Magnetic Force at the Present Time." The paper gave a historical sketch of the invention and improvements of the mariner's compass, and noted the discoveries which that instrument had made of the action of the magnetic forces in different parts of the earth. The lecturer connected the phenomena thus brought to light with the variations of the compass, a due regard to which was absolutely necessary for safe navigation. In one region of the globe—the smaller—this variation was westerly, and in the other—the larger—it was easterly. Westerly a variation prevailed in the Atlantic and Indian Oceans, and easterly in the Pacific Ocean. As a matter of fact the magnetic condition of the globe was always varying, but in what manner and to what end was absolutely unknown. Auroras and earth currents were then discussed, and notice was taken of the magnetic discoveries made during the voyage

of the Challenger. Having marshalled the various facts and hypotheses concerning magnetic phenomena, the lecturer in conclusion said, "Such are the facts, and how are we to interpret them? Whichever way we look at the subject of the earth's magnetism and its secular changes, we find marvelous complexity and mystery; lapse of time and increase of knowledge appears to have thrown us farther and farther back in the solution. The terrella of Halley, the revolving poles of Hansteen, and the more recent hypothesis of the ablest men of the day, all fail to solve the mystery."

**M.** DU MONCEL has recently communicated to the French Academy of Sciences a paper "On the Relation between the Diameter of Cores of Electro-Magnets and their Length," the conclusions reached in which are as follows: (1) The dimensions to be given to an electro-magnet should essentially depend upon the electric force which is to effect it, and upon the resistance of the circuit on which it is interposed. When the circuit is long and the electric source weak, the cores should be long and of small diameter; when, on the contrary, the circuit is short and the electric force intense, the core should be of large diameters. (2) For equal circuit resistances, the diameters of an electro-magnet established under maximum conditions should be proportional to the electro-motive forces. (3) For equal electro-motive forces, these diameters should be inversely as the square root of the resistance of the circuit, the resistance of the battery being included. (4) For equal diameters the electro-motive forces should be proportional to the square roots of the resistances of the circuits. (5) For a given electro-motive force and with electro-magnets placed in their maximum conditions the electro-motive forces of the batteries which excite them should be proportional to the square root of the resistances of the circuit.

**THE TRADE IN BOXWOOD.**—It appears that, in consequence of the continued increased cost of boxwood and its rapid decrease in quality, one of the principal importers of this and other hard woods into this country has succeeded in introducing two American woods to be used instead of box in the manufacture of shuttles, a purpose for which immense quantities of boxwood have hitherto been used. The woods so substituted are those of the cornel and persimmon. The first is apparently the *cornus florida*, a deciduous tree, about 30 feet high, growing abundantly in woods in various parts of North America. The wood, though of small size, is hard, heavy, and close grained, and is used chiefly in America for the handles of tools and for shuttle-making, and, when properly seasoned is much superior to Persian boxwood. The same may be said of the persimmon (*diospyros virginiana*), a tree belonging to the ebony family, a native of the United States, where it grows to a height of from 50 feet to 60 feet, and a diameter of a foot or 18 inches. The heartwood is of a dark brown color and very hard. The trunk is covered with a very thick, hard, and rugged bark. One great point to be particularly remembered in the preparation of

these woods for shuttle making is the very gradual drying by artificial means; this is more particularly recommended in the case of the cornel, undue haste in seasoning, it is said, having in some cases created a prejudice against the wood. As an illustration to some extent of the effects of the war, it may be stated that while in 1876 over 10,000 tons of boxwood were imported, the year just past shows a return of only between 4000 and 5000 tons. A large proportion of this wood is the produce of the forests on the Caspian Sea. Though the supply from the Black Sea provinces has for some years past been decreasing, it is well-known that untouched forests of the wood exist in Russian territory, and it is hoped and expected that at the close of the present disastrous war these forests may be opened up so that we may get abundant supplies of good wood for some time to come.—*Society of Arts Journal*.

**INFLUENCE OF TREES ON RAINFALL.**—There can be little doubt that there is a distinct connection between the rainfall and mean temperature of a country and the number of trees the latter may possess. Trees are magnificent regulators of climate. They are to it what the pair of revolving "governor-balls" are to a stationary engine. When the engine is going too fast, the "governor-balls" distend, and "throttle" or compress the aperture whence the motive steam-power is issuing. When the engine is working slowly, the balls droop, and so open the valve as to allow more steam to issue. The same with the woods and forests of a country. When the rainy seasons are on, every tree and plant absorbs some of the moisture, and stores it away in its own tissues. It thus prevents great quantities from flowing off the surface, and gathering into rills and rivulets, and so swelling the main rivers as to cause them to overflow their lowest lying banks. During periods of drought the leaves of the same forest give out the moisture they consumed into the atmosphere, and so prevent its being as dry and parching as it otherwise would have been. During the hours of night, also, the surfaces of the leaves become colder than the air, and thus the moisture contained in the latter is condensed upon them as dews. In many parts of Arabia this is the only kind of waterfall with which the parched earth is visited. The destruction of woods and forests, therefore, is always attended by an alteration of climate for the worse. It becomes more irregular. There are now alternate periods of rainfall and consequent floods, and of droughts. No country in the world has been so altered in this respect as the United States, for in no other has there been so much clearing of forest land within the last two centuries. In Italy great destruction of forests has taken place, and the summers are now more arid and hot in consequence. The reader will find in the Hon. G. Marsh's "Physical Geography as influenced by Human Action," a long list of parallel cases, where men have unconsciously modified the climate of the country in which they dwelt.—"*Watery Wastes*," by Dr. Taylor, F.G.S., &c.

# VAN NOSTRAND'S

## ECLECTIC

# ENGINEERING MAGAZINE.

NO. CXIV.—JUNE, 1878.—VOL. XVIII.

### RIVER IMPROVEMENTS IN FRANCE, WITH AN ILLUSTRATED DESCRIPTION OF THE LATEST EXAMPLE OF CHANOINE'S SYSTEM OF FALLING GATES.

By PROF. WILLIAM WATSON, Ph. D., late U. S. Commissioner

#### III.

##### MODIFICATIONS OF THE LOCK AND BARRAGE AT PORT A L'ANGLAIS.

On account of the great distance, 24,600 meters, between the two barrages at Port a l'Anglais and Surrennes, one situated above and the other below Paris, and in consequence of abandoning the idea of constructing a barrage in Paris itself, the depth of the lower bay, behind the lock at Port a l'Anglais, had to be increased 1 meter, and vertical walls had to be substituted for the sloping ones. In order not to interrupt the navigation during the reconstruction of this lock, which is on the left side, a great breach was made on the right, in the over-fall, through which the traffic passed; this was afterward closed by a movable dam with gates. The old navigable pass, which had a width of 54.70 meters, has retained its gates raised by means of a boat; the over-fall, or weir, reduced to 37.90 meters, is separated from the pass by a pier 3 meters thick; the gates of the over-fall are worked from a service-bridge.

##### NEW PASS OR "PERTUIS NAVIGABLE."

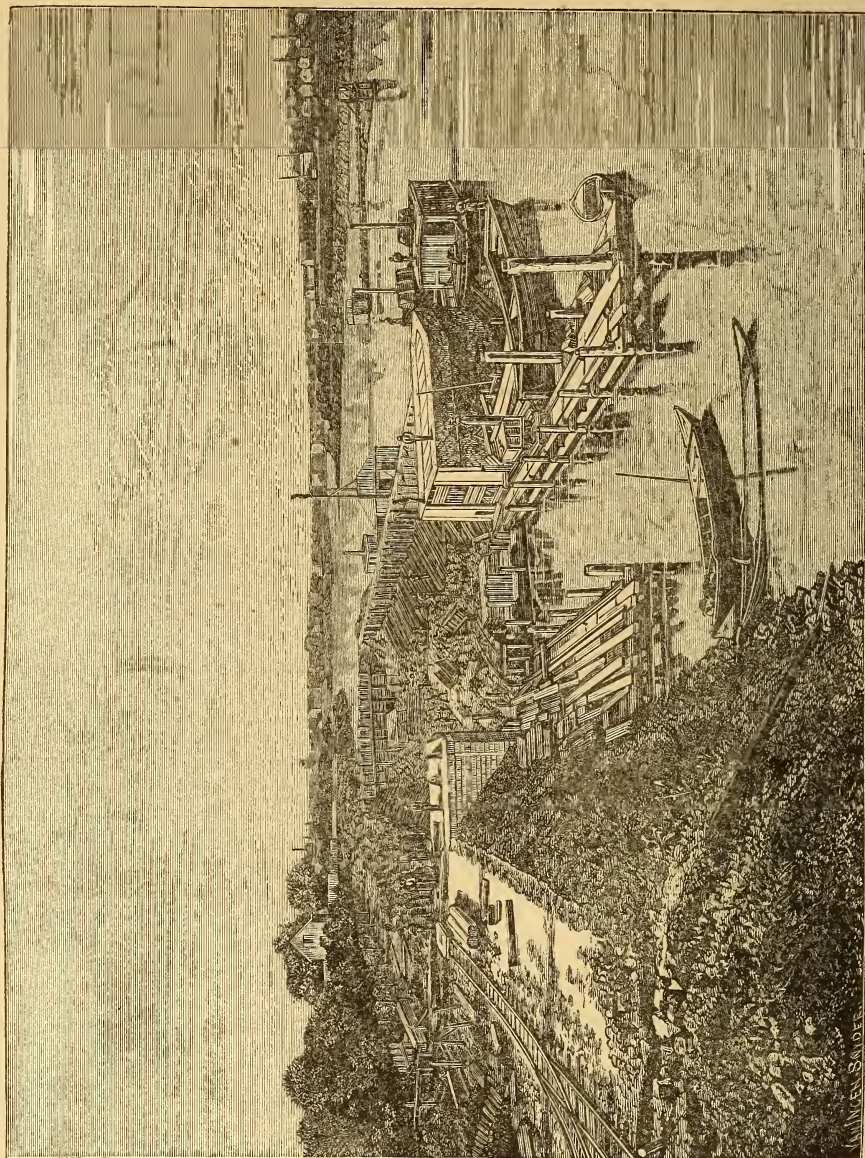
The new pass or navigable Pertuis of the barrage at Port a l'Anglais has a clear space of 28.70 meters between the

piers. It is closed by twenty-six falling gates of Chanoine's system. Its sill is 70 centimeters below that of old pass, which is closed by gates 3 meters high. The new movable gates rise to 3.70 meters above their sill. In order to support so great a head of water, changes had to be made in the models heretofore adopted by M. Chanoine. They were as follows:

1st. The width of each pannel was reduced from 1.20 meters to 1 meter, with the same interval of 10 centimeters between each pannel. The wood-work has also been simplified; it is formed of two uprights united by four transoms. The uprights are 3.86 meters long and 0.30 meter by 0.20 meter section.

2d. The inclination of the pannel to the vertical, which was 8° in the model of M. Chanoine, was made 20°, to diminish the effort tending to raise the sill from its bed.

3d. When a pannel is lowered it bears upon four cubes fixed into the platform bed; the gate is raised by two handles fixed to the uprights. By this arrangement the pannel is perfectly sustained, and no change of form in the wood-work is to be feared.



MOVABLE DAM ACROSS THE SEINE. GENERAL VIEW.

## PLATE A.

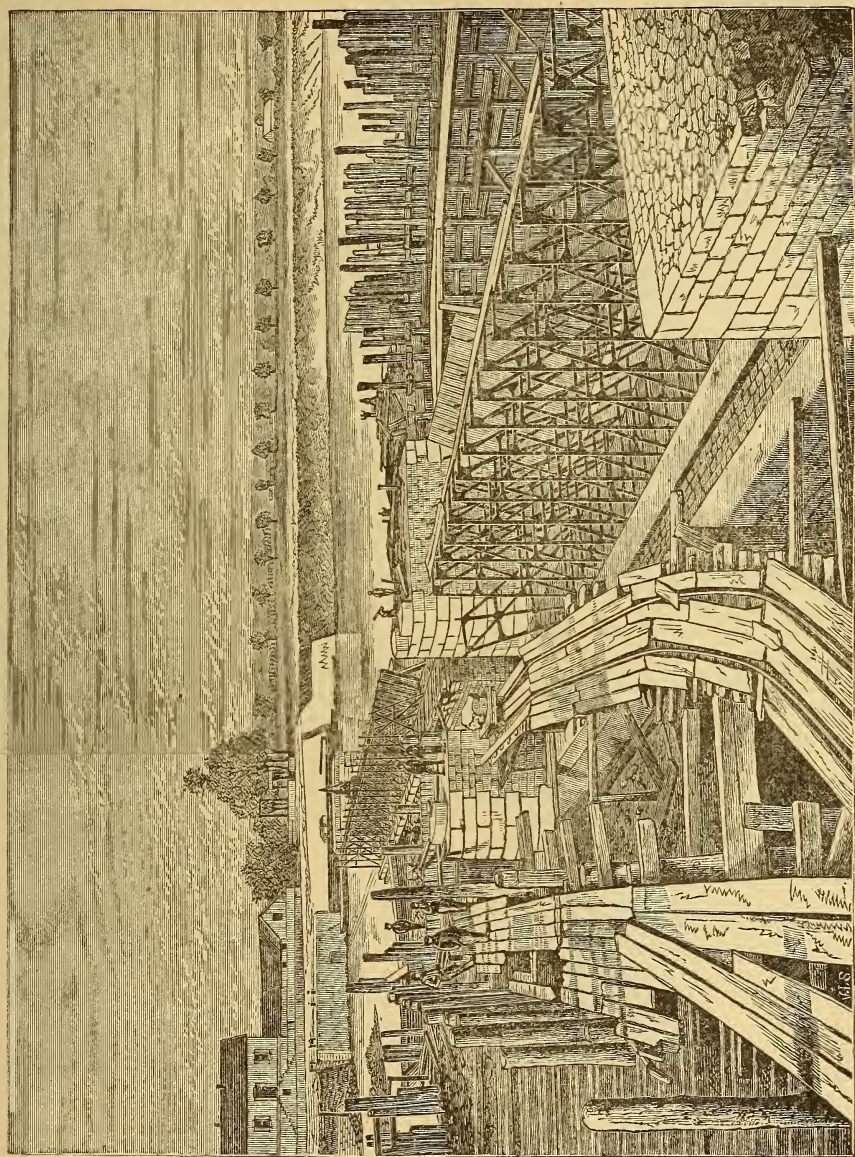
## MOVABLE DAM ACROSS THE SEINE—GENERAL VIEW.

Plate A represents a general view of the movable dam across the Seine, at Port a l'Anglais, four kilometers above Paris.

The view is taken from below, looking up-stream. At the extreme right is the great breach in the weir, made to provide a channel for the traffic while the lock was being rebuilt. At the left of this breach is the weir, now reduced to a length of 37.90 meters, with its gates lowered. It is separated from the old pass by a stone pier three meters wide, situated in the middle of the river. At the left of the pier is the old pass, 54.70 meters wide; its gates are lowered, and as the sill is 1.10 meters below that of the weir, they are consequently submerged.

At the extreme left is the lock as it appeared during the process of reconstruction. This process consisted in lowering both the chamber floor and the tail miter-sill a depth of one meter, and also rebuilding the side walls.

The total length of the lock is 210 meters; its width, 16 meters, allows it to contain a double line of boats. A depth of two meters is retained upon the tail miter-sill from the next dam below, at Suresnes. The head miter-sill is unchanged, so that the lift-wall is one meter in height. At the side of the lock are seen the pile-drivers and pumping-boats used in rebuilding.



MOVABLE DAM ACROSS THE SEINE. NEW PASS, OVERFALL, AND OLD PASS

## PLATE B.

## MOVABLE DAM AT PORT A L'ANGLAIS—NEW PASS, WEIR, AND OLD PASS.

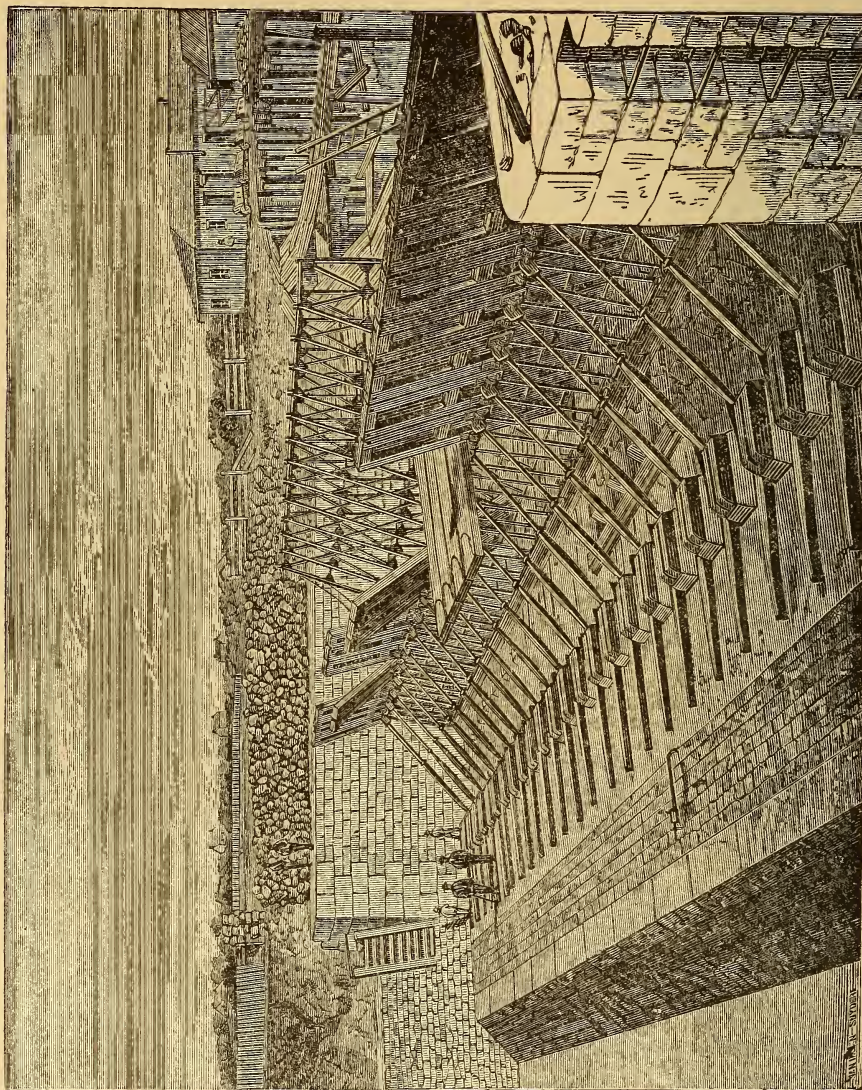
Plate B represents the movable dam at Port a l'Anglais, as seen from the shore on the right, looking down-stream.

At the right is the new pass, with its iron *fermettes* and the gates. Seventeen of the *fermettes* are erect, and the eighteenth is half raised.

At the left of the pass is the weir, with its twenty-seven automatic falling-gates. In front of these is a service-bridge, carrying a lifting-windlass. The sill of the weir is 1.80 meters above that of the pass.

At the left of the weir is the old pass; its sill is 1.10 meters below that of the weir; the gates are down; they can be raised by means of a maneuvering-boat, and lowered by a capstan and talon-bar.

Still farther to the left are the tail-walls of the lock; and beyond, the lockman's house.



MOVABLE DAM ACROSS THE SEINE. NEW PASS SEEN FROM BELOW.

## PLATE C.

## NAVIGABLE PASS AT PORT A L'ANGLAIS.

Plate C represents the new navigable pass at Port a l'Anglais, as seen from below, looking upstream.

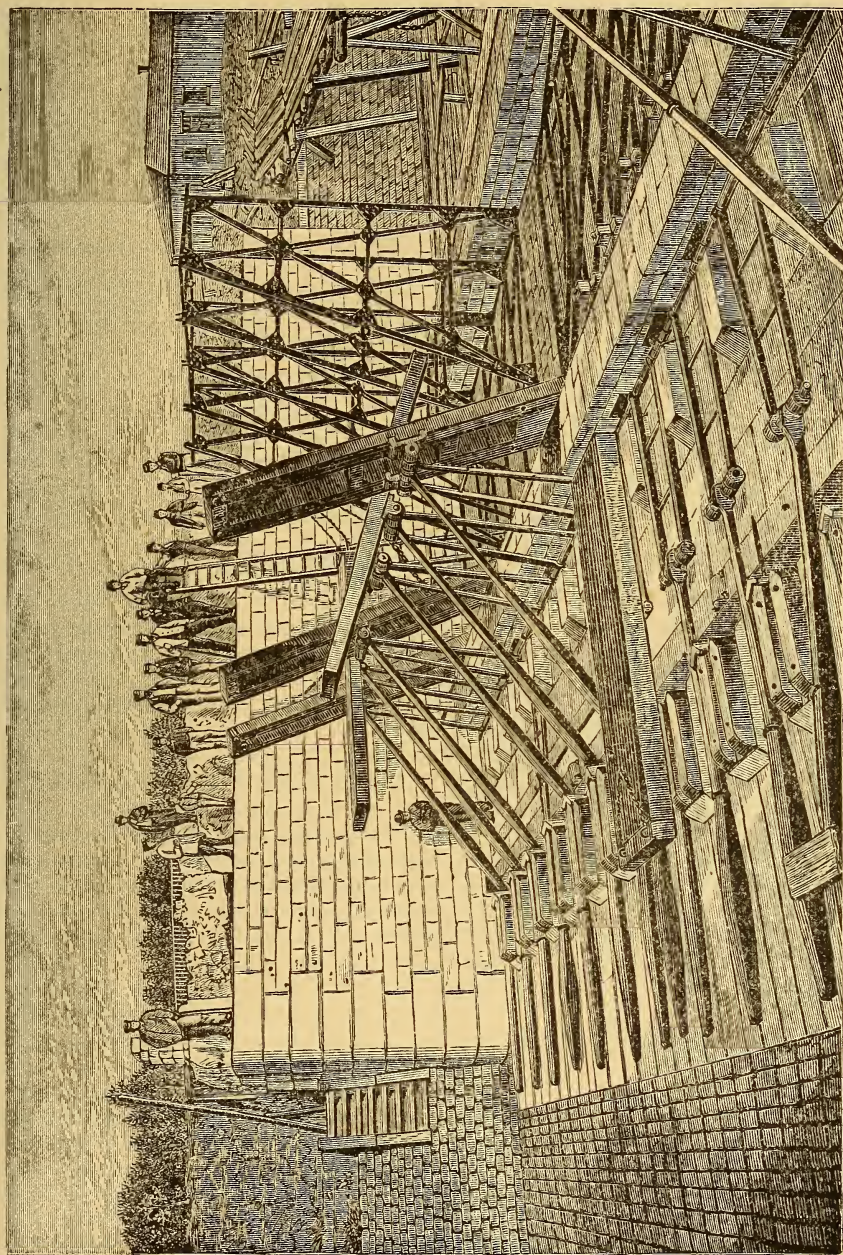
The opening of the pass is 28.70 meters. It has 26 gates and as many *fermettes*.

The draught on the sill in the lower bay usually exceeds 0.70 meter; that in the upper bay, maintained by the gates, is 3.70 meters; the strength of all the parts of the structure has been calculated on a supposition that a sheet of water 0.40 meter thick flowed over the tops of the pannels; that is, it has been calculated to resist a pressure due to a difference of level of 3.80 meters between the two bays.

Angle of the gate with the horizon is..... 80°  
 Angle of the abutment-prop with the horizon is..... 37°

Kilograms.

Total pressure on a pannel is..... 9,300  
 Total pressure on the head of the horse..... 7,422  
 Compression of the abutment-prop..... 9,051  
 Tension on the horse... .. 2,920  
 Bending moment of the pannel..... 2,746



MOVABLE DAM ACROSS THE SEINE. A PORTION OF THE NEW PASS AS SEEN FROM BELOW.

## PLATE D.

DETAILS OF THE NAVIGABLE PASS AT PORT A L'ANGLAIS.

Plate D represents a portion of the new pass as seen from below, looking up-stream, with the gates and *fermettes* in various positions.

*Horses.*—Each horse is in the form of a trapezoid, 1.90 meters high, 0.76 wide at the base, 0.50 at the top. It weighs 190 kilograms. The abutment prop weighs 270 kilograms, and is calculated to resist a compressive stress of 9,000 kilograms.

*Sill.*—The sill is composed of three pieces: the first holds the journal-boxes of the horses; the second receives the pressure of the horses, and the third the shock of the gates when they are first raised.

*Fermettes*.—Each *fermette* has the form of a trapezoid, 4.75 meters high. The upper base, which supports the flooring, is 1.20 meters long; the lower base, or axle, is 3.10 long; the upstream post is 4.80 meters high; the down-stream post is inclined at 5 vertical to 2 base, and the brace 3 vertical to 2 base.

Beside the brace, the *fermette* is stiffened by three horizontal transoms and a fourth inclined, and forming with the brace a Saint Andrew's cross. Except the lower axle, which is a cylinder 0.08 meter in diameter, each piece of the *fermette* is of U-iron, an economical arrangement, as equal weights of U-iron have a much greater transverse strength than square or even T iron, since the material is farther from the neutral axis.

The joints are easily made, and the weight per running meter is less than that employed in the construction of M. Poirée's smaller *fermettes*.

All the joints are stiffened by gussets of plate-iron 0.007 meter thick, and in addition by wrought-iron knees at the four corners of the trapezoid.

The knees of the upper angles have gudgeons, which receive the connecting rails upon which the maneuvering-windlass rolls, and also the link-catches that hold the gate chains.

*Strength of the fermettes*.—Each *fermette* has been arranged so as to withstand from its cap a pull from the maneuvering-chain of 3,000 kilograms at an angle of 45°.

4th. In the primitive model of M. Chanoine, the axis of rotation is placed at five-twelfths of the total height. For the new gates at Port a l'Anglais this arrangement would give to the breach a height of 1.60 meters; 1.75 meters was given to it, and the axis of rotation was placed 15 centimeters below the center of figure. This arrangement prevents these pannels from spontaneously falling, an inconvenience which was experienced in the older ones, when the water in the lower bay was very high and the falls unusually reduced. This inconvenience has actually been remedied by placing between the uprights little automatic valves, turning around a horizontal axis and having the dimensions of 100 by 42 centimeters. These butterfly-valves, as they are called, open spontaneously before the pannel falls, and the lock-man shuts them at the proper time, with great ease, by means of a boat-hook from a boat passing along behind the bar-rage.

5th. Instead of being satisfied with a maneuvering boat to raise the great pannels of the new pass, there has been a service-bridge established above, composed of *fermettes*, of Poirée's system, upon which the lifting-crab rolls. The *fermettes* of the bridge are 4.75 meters high, 3.10 meters wide at the base, and 1.20 meters at the top. Each *fermette* is placed exactly in front of the middle of each pannel, and the flooring of the bridge is 50 centimeters above the level of the lower bay. The uprights, the ties, and braces are formed of U iron, 8 centimeters wide, 35 millimeters high, and 7 millimeters thick.

The expense for lowering the lock at Port a l'Anglais:

	Francs.
The rebuilding of the revetment walls of the lock-chamber is...	372,056.74
Cost of the navigable pass.....	225,000.00
Total.....	597,056.74
Previous cost.....	983,675.62
Total cost.....	1,580,732.36

The interest of the cost of all of these works, together with the annual expense of repair, represents, for the mean actual traffic, 2 centimes per ton per kilometer upon the Yonne, and 1 centime upon the Seine.

#### COMPARISON OF WATERWAYS WITH RAILWAYS.

When we may choose between a water-line and a railway between two given points, the latter is usually less sinuous than the former, and we may admit that 1,000 feet by water are equivalent to 800 feet by rail.

Under these conditions the average price of a ton of merchandise by the two ways is as two to three—in other words, the railway augments 50 per cent. the price of transportation, but it offers in return the advantage of speed. In 1869 the freight on a ton of coal from Mons to Paris was \$1.28 by water and \$1.84 by rail. These prices are about in the ratio of 2 to 3 as indicated above.

The freight is about equally divided between the railway and the waterway, and we may say, as far as commerce goes, these two are equivalent, each having its advantages and its disadvantages.

Upon the most prosperous portion of the system of inland navigation, especially in the North, the activity of freight by water is comparable with that upon

the railways; it has been increasing for the last twenty years, and has effectually contested the monopoly of the railways, and thus contributed largely to diminish the cost of transportation.

Finally, if we suppose the difference in the cost of transportation of one ton one mile to be one-third of a cent, applied to the 1,500,000,000 of mile tons which annually pass through the French rivers, this difference would annually amount to \$5,000,000, an economy in the reduction of the price of articles of first necessity.

We must hence conclude that naviga-

ble waterways are indispensable, not only where the means of transportation are scarcely developed, but also in one which is largely served by a complete network of roads and railways.

The total tonnage on the railways is 4,000,000,000 mile tons.

These facts would have little value were it not that within a few years the improvements above mentioned have taken place in the construction of movable dams and river-gates, so as to permit, easily and with comparative little expense, rivers heretofore not navigable to be converted into canals.

## ON THE STRAINS DEVELOPED IN A BEAM.

BY JOHN D. CREHORE.

Written for VAN NOSTRAND'S MAGAZINE.

On page 467 of the May number of the Magazine, Professor De Volson Wood removes my suspicion "that no late authority disputes the equality of the total moments on each of the two sides of the neutral surface," by disputing it himself. Now I most cheerfully admit that his presentation of the case enables me to see that these two moments *may* be unequal, but not that they *must* be unequal; and hence the reasoning by which he infers that these moments *must* be unequal is not sound, as I will now show.

What I have to say at this time is based upon the uncorrected proof of Professor Wood's article above cited. I see no defect in the argument till we reach this sentence: "The forces producing tension tend to turn the system in the same direction as those producing compression,—in this case right-handed,—hence they have the same sign and can not be equal to each other."

Now is this impossibility of equality inferred from the sameness of signs of the two resultants of tension and compression? In a previous paragraph we find these words: "The only horizontal forces in this case are the pulls and pushes of the forces in the section. Let  $t$  be the sum of the tensile forces and  $c$  the sum of the compression forces in the section  $ab$ , then we have

$$t + c = 0$$

$$\therefore t = -c;$$

or they must be equal and contrary."

Here we are told that the sum of the tensile forces must be equal to the sum of the compression forces, and the signs contrary; and there, when the significance of the sign has been changed, as in passing from a rectangular to a polar system, we are told that these same quantities (the sum of tensile and the sum of compression forces) "have the same sign and cannot be equal to each other." Does not likeness of sign, in the rotation system, for two horizontal forces, one above, the other below the axis of rotation, mean the same thing as contrariety of sign in the other system, for the same two horizontal forces acting in opposite directions?

The writer, then, probably means to say that these forces have the same sign and their *moments* cannot be equal to each other. For he goes on as follows: "Draw  $od$  horizontal and take  $e$  directly under  $P$ ; then will  $oe$  be the arm of the force  $P$ , and  $od$  that of  $V$ . Also let  $T$  be the resultant of the tensile forces, and  $f$  its arm, and  $C$  and  $g$  the corresponding quantities for the compression ones, and we have

$$T.f + C.g + P.oe - V.od = 0 \quad (1)$$

The values of  $P$  and  $V$  can not both be

made to disappear at the same time from the equation, hence we cannot even have

$$T.f = -C.g$$

for equilibrium."

To this I reply, we do not require

$$T.f = -C.g$$

in the polar system, but we must always have, in this system, whether we require it or not,

$$T.f = C.g$$

whenever  $f=g$ ; for T, the resultant of the parallel tensile forces, is equal to their sum  $t$ , and, similarly,  $C=c$ . But  $t=\pm c$  according to the system of signs we use; therefore  $T=\pm C$ ; and, if  $f=g$ , we must have

$$T.f = \pm C.g$$

according as the algebraic sign indicates direction of rotation, or horizontal direction of push or pull.

Equation (1), therefore, does not enable us to say whether  $T.f=C.g$  or not. The equality of these two moments depends entirely upon the equality between  $f$  and  $g$ ; that is, upon the equality of the distances of the points of application of the resultants, T and C, from the neutral axis. For C and T are axiomatically equal; that is to say, every push to the right must be balanced by an equal pull to the left, for equilibrium. And this is the axiomatic truth which I should have announced in my article published in this Magazine for August, 1877, instead of the assumption that the moments must be equal.

With Navier, and Barlow, and Kent, I was probably led to make this assumption from the analogy of the particular kind of forces under consideration to statical moments. That is, the strain on any given fiber is assumed to be equal to the strain on a fiber at the unit's distance from the neutral surface, multiplied by the distance of the given fiber from that surface. Thus each force so expressed has the form of a moment. This I offer not as an excuse, but as an explanation.

I am especially grateful to Mr. William Kent for ably instituting this discussion, and to Professor Wood for being instrumental to my perceiving that the hypothesis of Navier may not always be the correct one, even within the elastic limits.

And now what shall be said of the accordance between the formula deduced from Navier's hypothesis, and the results of a wide range of experiments upon solid rectangular beams? Simply this: The equality of the expressions, which were called moments at the instant of rupture, still subsists, but the expressions may, or may not, represent those moments.

The three expressions erroneously written in my article above referred to, viz.

$$\frac{1}{3}Tb(h-x)^2 = \frac{1}{3}Cba^2 = \frac{1}{3}Bb(\frac{1}{2}h)^2$$

are similar functions of the ultimate resistances T, C, B, of material, to tension, to compression, and to cross-breaking; and the resulting formula

$$B = \frac{4C}{(1 + \sqrt{\frac{C}{T}})} \quad (2)$$

is no longer to be considered as theoretically true, except for cases where the lines of action of the resultants of tension and compression are equally distant from the neutral surface; but the formula becomes empirical, like the Hodgkinson, or the Gordon formula for pillars, and worthy of confidence according to the number of experiments by which it is satisfied.

Therefore he who publishes the results of careful experiments determining the three resistances T, C and B, for any given material, does a service similar to that rendered by Mr. Thomas D. Lovett, in reporting experiments made upon wrought iron pillars to verify the constants in the Gordon and Rankine formulas.

I have accordingly read with much interest Professor R. H. Thurston's "report on the tests of three bars of No. 2 and of three bars of No. 4 Salisbury cast iron," published in the Railroad Gazette of Nov. 30th, 1877.

His average results are:

	C	T	B
No. 2,	87,429	20,500	45,760
No. 4,	127,323	34,407	67,035

But by equation (2) we have for

$$\begin{aligned} \text{No. 2, } B &= 87,224 \\ \text{No. 4, } B &= 59,580 \end{aligned}$$

The mean of the Hodgkinson experi-

ments on cast iron requires the  $B$  of formula (2) to be augmented by  $\frac{1}{3}$  of itself. Giving our computed values of  $B$  this increment, we find for

$$\text{No. 2, } \frac{1}{3} B = 41,360$$

$$\text{No. 4, } \frac{1}{3} B = 66,200$$

Both of these values are less than the experimental numbers; and this was to be expected, since the tests for transverse resistance were made upon bars one inch square, the tests for tensile strength upon "each of the broken transverse specimens, formed into a tension specimen 0.798 inches in diameter," and the tests for resistance to compression were upon "accurately turned cylin-

ders, each of which was two inches in length and one-half inch in diameter. They were prepared from one of the pieces taken from each bar after having been tested by transverse stress."

In the absence of any statement to the contrary, it is presumed that these inch bars, when tested for transverse strength, were as they came from the foundry, and as they would be employed in structures, with their outer "crust" unremoved,—a circumstance which may well account for the excess of the actual breaking resistance of the square bars over that computed by the formula, from tests upon the inner portion of the same metal.

## IMPROVEMENT OF THE ST. JOHN'S RIVER (FLORIDA).

By CAPTAIN JAMES B. EADS.

Abstract of a Report to the Municipal Board of Jacksonville, Florida.

A PERSONAL examination of the mouth of the St. John's River, and a study of the official surveys of the bar and river, together with such other reliable data in connection therewith as I have been able to obtain, confirm the following facts:

The territory drained by the St. John's River comprises an area of about 7,500 square miles. The average rain-fall upon this area during the last twenty-seven years equals 50.27 inches at Jacksonville, and about 60 inches over the more southern portions of this area.

The mean tidal oscillations at Fort George's inlet, near the mouth of the river, are five feet and four-tenths; the highest observed tide being seven feet and one-tenth above the plane of reference, and the lowest one foot and two-tenths below that plane; the extreme range being eight feet and three-tenths.

The oscillations at Pilot Town, within the mouth of the river, and distant about three statute miles from the outer edge of the bar, are nearly one foot less. At Jacksonville the mean rise of the tide is but nine-tenths of a foot. The river is quite tortuous, the distance between the Jacksonville wharf and Pilot Town being fourteen statute miles in a direct line, while by the line of deepest water or

river channel, it is twenty-four miles. The width of the river at low water immediately above Pilot Town is about 1,740 feet, and its greatest depth at mean low tide at this point, is 36 feet, its sectional area here at low water being about 36,000 square feet. This is the narrowest part of the river below Jacksonville. At Jacksonville it is about 2,000 feet wide, with a maximum depth of 12 fathoms. Its greatest widths, between these towns are at Dunn's Creek and Mill Cove, ten and thirteen miles respectively below Jacksonville. At the first place it is 2.2, and at the last, 2.8 miles wide.

The average width of the river, between Jacksonville and Pilot Town, is one mile. A mile below Pilot Town the shores of the river gradually widen out to the sea. The southern bank, a bluff one, twenty-five or thirty feet high, trends off east-southeast, or nearly at right angles to its direction opposite Pilot Town, while the northern shore, a low, marshy one, bends around to north-northeast, which general direction it follows for about a mile, when it trends quickly around to the north, its low, compact sandy beach receiving the full force of the waves of the Atlantic for a

mile beyond, at which distance the shore-line is interrupted by Fort George inlet.

About two miles and a-half by the shore-line of the river, above Pilot Town, Sister creek or inlet enters the St. John's on the north side, and by a tortuous channel about 400 feet wide, having a general direction to the north, connects the Nassau and Amelia rivers with the St. John's and furnishes an inland navigation to Fernandina for vessels of five or six feet draught during flood tide.

About midway between the St. John's and Nassau rivers, the Fort George inlet connects the Sister inlet with the Atlantic Ocean, and separates Fort George Island from Talbot Island. Both Talbot and Fort George islands are subdivided by a small inlet running north and south, by which another inland connection is made between the St. John's, Fort George inlet and Nassau River. This last-named inlet, through Fort George Island, is called Haulover Creek.

The width of the river's discharge, measured along the outer two fathom contour of the bar crest, and at right angles to the outflowing current, is nearly three miles.

The shoals which occupy the fan-shaped area, inclosed between this contour line and the expanding banks of the river, constitute the St. John's bar, and cover an area nearly three square miles in extent.

An inspection of the different surveys of the bar, and information derived from several intelligent and experienced pilots, confirm the belief that the deepest channels which have existed through the bar, have occupied, at various times, almost every part of this extensive area.

At present the river struggles to reach the sea through three well-defined channels. One of these, called on the charts the Pelican channel, lies nearly in the direction of the axis of the river volume where it leaves the plainly defined shores of the stream. This channel extends eastwardly between two large and prominent shoals, both of which are dry at half tide; one of these is called the North Shoal, and the other Pelican Reef. South of Pelican Reef, a still deeper channel is found, which follows the south shore so closely and so far around, that the St. John's River light is finally hid-

den by the shore from the view of a vessel passing out through it, and then the channel suddenly bends to the east and enters the ocean. This is called the south channel, and at present it is the deepest one, having at mean high tide about 10 ft. on it. Before the light-house is lost from view when in it, this channel throws off a branch to the east, called the middle channel, through which nine feet can be carried at high tide.

The material forming the bar is essentially the same which forms the sand beaches to the north of the river's mouth, the bottom through the various channels on the bar being compact, and so firm as to endanger the hulls of vessels crossing it in heavy seas by thumping the bottom of the channel. Those unfamiliar with the subject would infer from its firmness that it would yield but slowly to the action of the current, whereas no material is more sensitive to any disturbance of the equilibrium of forces which causes it to come to rest, than the sand composing such bars.

An examination of the meteorological records of the United States signal service for the past five years, for which I am indebted to Mr. Gosewisch, in charge of the office here, shows that the prevailing winds are from the northeast. The mean of the five years being 7.2 months during which the wind was from the north or northeast. We may therefore reasonably infer that the prevailing littoral, or shore current of the sea, flows southward in front of the river's mouth during the same period of time.

The height and protrusion of the southern bank of the river into the sea would indicate the presence of a current to the south during most of the year, for the general tendency of all silt, or sediment-bearing streams entering the sea at right angles to prevailing sea currents, is to have their mouths turned around towards such currents as though opposing them.

This is because the sedimentary matters discharged by the stream are carried by the sea currents across the mouth of the stream, and deposited on the shore beyond. The constant accumulation of earthy matters on that side causes that bank to grow more rapidly out into the sea than the other, and as these matters continue to accumulate upon it, the

course of the river is gradually forced around, by the deposits on that bank, into a direction apparently in antagonism with the sea current.

During the greater part of the remaining four months and a fraction, it is quite likely that the sea current runs in the opposite direction, or to the north, as the wind is during those months chiefly from the southeast or south.

As the St. John's carries but little sediment to the sea, the bar, at its mouth, is of the kind known as drift bars, a term used to distinguish them from those formed by alluvious or river deposits at the mouth of delta rivers, such as the Mississippi, the Danube, the Dwina, the Rhone, etc.

Over the profounder depths of the ocean the water constituting the waves simply rises and falls vertically, like the material of a carpet when spread out horizontally, and shaken by men standing around it. The waves move horizontally, one after the other, but little or no horizontal motion of the water occurs as a result of the progress of the waves alone.

But the case is quite different when the water in its vertical descent feels the resistance of the sloping bottom of the shore. A horizontal motion in the water is then produced, slight at first, where the shore is deep, but increasing as the depth diminishes, and always moving shoreward. As the waves increase in height the horizontal motion becomes so swift in depths of from one to three fathoms, that the water of the advancing wave-crest rushes rapidly forward and falls over the water in the trough before it, and thus forms what are termed breakers.

Observations of tidal waves have established the fact that the velocity of such waves is greatly influenced by the depths over which they pass. In fifty fathoms the velocity is about sixty miles per hour, while in 5,000 fathoms it is about 528 miles. The waves produced by the winds are similarly affected by depth. Their velocity is, consequently, arrested as they approach the shore. Those nearest the beach are overtaken by those which follow, and which are in deeper water, and overwhelming at recurring intervals, those in advance of

them increase the height of the breakers in rythmical periods.

The shoreward or horizontal motion imparted to the water is called translatory motion, and the rapidity and distance to which the ocean-swells are driven out upon its sloping beaches illustrate its action. Consequently, wave-action in shallow depths near the coast has a constant tendency to sweep up the sands in such depths and deposit them on the shore. Under the operations of these almost incessant forces, which are heaping up the sands on the shore, and the opposing influence of gravity inclining them to run back again, the beach assumes a certain inclination or slope, which is called the angle of repose. This angle is altered when the wave force, creating the motion of translation, is intensified by storms, and it is steeper or flatter according to the character of the material brought shoreward by the waves. Shingle and coarse sand assume steeper slopes than quicksand, which is composed of rounded particles, and that which is left above the mean range of the tide is steeper than that which is constantly submerged. The more violent are the waves, the greater will be the depths from which sand, shells, loose stones, etc., will be swept up, by this motion of translation, on to the shore.

From this it is evident that every river emptying into the sea, unless under exceptional conditions, must struggle through the sands that are thrown up shoreward by the waves. These, in reality, are continually striving to barricade the river current and prevent it from entering the sea. In the contest, the river forces, under the ever-varying intensity of hydrostatic pressures resulting from freshets and tides, are as constantly sweeping down the sandy barriers thrown up by the waves, and, seeking out the lines of least resistance, the river flows through continually shifting channels across the bar.

In this external warfare of opposing forces, the sands at the river's mouth are driven first in one direction and then in another; at one time by the tides at another by the river, and again by the waves over the whole area of the bar, constantly extending it into the sea, by

the accumulations of the river sediment and the ocean sands, until it is built out so far seaward that its further growth is retarded or stopped altogether, either by the currents of the sea, or by the steepness of the shore line, or by both causes combined.

It must be evident from this simple explanation, that the extent of the shoreward movement of the sands caused by wave action, is increased by the height of the waves, and that it decreases with an increase of depth.

The sands in four or five fathoms of water are but little disturbed by wave action, except in storms, although even large stones have been moved by the waves of very violent storms in much deeper water.

If the discharge of a river in a tideless sea requires a certain width and depth of channel for its accommodation, and the natural cross section be too wide and shallow, we may safely assume that if the width be reduced by compelling the water to flow through artificial banks, such as jetties or piers, the depth will be proportionately increased in the narrowed channel between the jetties. If the volume be so great as to give a depth of twenty feet between the jetties, we may safely assume that none but storm waves will have power to move the sands on the ocean's bed in front of the channel; while the river-current, being thus concentrated, would be more potent to repel the advancing current induced by the waves and thus neutralize its effects. As storms are of brief duration, while the outflow of the river is more or less constant, it is plain that such jettied channel would maintain such depth as the volume of the river demanded, almost if not wholly irrespective of the effects of the translatory action of the waves. It must likewise be evident that the deeper the channel between the jetties, the less liable will it be to even a temporary diminution in depth from the effect of storms.

This only supposes such artificial contraction of width is made to the mouth of a river discharging in a tideless sea, and having sufficient volume of discharge to maintain a depth of twenty feet or more through a jettical channel of the requisite width.

Let us suppose that jetties be applied

to the St. John's, and assume, for the time being, that no fresh water at all is discharged by the river into the sea. We will, then, have the conditions reversed; that is, we will have no river discharge, and we will have a mean rise and fall of tide equal to five and a half feet. Leaving out of consideration the magnificent lacustrine river above Jacksonville, we find extending from Jacksonville to the sea, a river basin twenty-five miles long, and averaging one mile in width. At one end of this basin the average rise of the tide is nearly one foot and at the other end five and a half feet. The average quantity of tidal water passing into and out of this basin twice a day, is therefore equal to nearly 2,000,000,000 cubic feet. This would produce an average rate of current equal to two miles per hour, through a channel having a cross-section of 30,000 square feet, or a maximum current during average flood and ebb-tides of about four miles an hour.

With such a tidal basin, *even without the additional advantage of the river current*, resulting from a large annual rainfall upon 7,500 square miles drained by it, I should have no hesitation in recommending the application of parallel jetties at the mouth of the St. John's river, as a certain means of permanently deepening the channel through the bar at its mouth. Every inlet into the sounds or tidal basins which border the eastern sea coast of the United States, is an evidence of the ability of the ebb and flow of the tides to maintain a depth of channel from the ocean into these basins, and to resist the influence of the wave-action, which would otherwise soon shut off these basins from all connection with the sea. The depth of these channels is determined by the volume of tide water forced through them in filling and emptying the different basins into which they lead, and by the width of the inlet. If the latter be artificially contracted, the depth of the channel will be increased and the quantity of water received and discharged by the basin will be greater, because the flow of water is retarded by the friction caused by its contact with the bed of the channel. If the channel be narrowed and deepened, the frictional surface will be lessened and the basin will fill faster. The friction that must

be overcome by the water in passing in during flood tide over the great expanse of the St. John's bar causes the tide to rise one foot less in height inside the bar at Pilot Town, than it is outside of it at Fort George inlet. Hence, if jetties were applied to reduce the width of the inflowing waters, now nearly three miles wide, and they were caused to pass through a channel only three or four-tenths of a mile wide, the frictional resistance would be greatly decreased, and higher tidal oscillations would occur at Jacksonville. The river channel would, therefore, not only be deepened over the shoals in the river by a higher plane of water at high tide, but the increased flow of tidal waters through the river would deepen the bottom likewise and materially improve the navigation of the river.

The size of the river at Pilot Town immediately above the bar, where it is exceptionally narrow, furnishes more reliable means of determining the width and depth of channel that can be maintained across the bar with the desired depth between parallel works, than any mathematical formulas, relating to the flow of water; for there are so many influences which patient experimental investigation would fail to correctly estimate, tending to modify the results of any strictly technical solution of the question, that such method would be unreliable. The bends of the river, the width of its bed, the irregularity in the flow of the tides, and the difficulty of determining the varying volume of the river's discharge, all influence the result, and all conspire to maintain the size of the channel at the point referred to. At this point we find that by the combined influence of the tides and fluvial discharge, the currents maintain a section 1,740 feet in width, with a maximum depth of thirty-six feet, the area of the section at half tide being 36,000 square feet. This maximum depth could not be secured at the sea ends of the jetties with the width found at this point, for the reason that under the influence of the waves of the ocean, the bottom of the channel there would assume a flatter shape than in the river.

The width of the channel to be determined through the jetties should not only be considered with reference to

commercial requirements, and to the amount of water to be discharged through it by the combined volume of the river and the tides, but also with reference to the cost of construction and maintenance of the works, for these will be more expensive in proportion as the channel is deeper, and the channel will be deeper in proportion as it is contracted by the jetties, within certain limits.

The width found at Pilot Town, say 1,700 feet, is sufficient to secure a judicious mean between the probable demands of commerce, and an economic expenditure for construction and maintenance. This width I feel confident will produce a reliable channel of, at least, twenty feet in depth at average flood tide. The depth will more probably be twenty-three or twenty-four feet, through jetties placed at that width.

The most judicious location for the jetties can only be determined by a careful survey, which survey, owing to the shifting nature of the channel through the bar, should be made immediately before commencing the work. A permanent artificial channel can be made through almost any part of the bar, but the location which will produce the best results for the least expenditure, can only be determined after such survey as I have suggested. The direction of the jetties' channel should be such as to furnish the longest straight line of current into the river, as the in-flow of the tide will be diminished by bends in the channel. Its discharge should be as nearly at right angles to the littoral currents as may be practicable with the desired straightness of inflow. On the accompanying chart I have indicated such alignment of the works as I have deemed most judicious for the conditions shown by it. It is possible that a survey immediately preceding the construction of the jetties may show no important difference in the form of the bar, and in such event I would make no alteration in the location shown on the chart.

The mode of construction should be similar to that used at South Pass. Although willows cannot be conveniently obtained in the vicinity, other materials are at hand in abundance with which to construct brush mattresses for the work. Palmetto piles can likewise be abundantly obtained, and as these are not attacked

by the toredo, they can be advantageously used to lessen the amount of stone that would otherwise be required.

When the construction of the works is begun the foundation courses of mattress for both jetties should be laid, from the land to the sea end of the jetties, before any portion of the work is built up to its full height. The height of the jetties should be at least two feet above mean high tide.

I have made an estimate of the total cost of the proposed works, which is based upon the most reliable data I have been able to obtain. While the cost may be considerably modified by the results of subsequent surveys, and by the skill and experience of the engineer who may be charged with the execution of the works, and while the estimate necessarily only approximates, it will be found sufficiently accurate and reliable to base legislative action upon, and sufficiently liberal to insure the execution of the work by competent persons, for the sum named. A more exact estimate can only follow a careful and thorough survey and the preparation of detail drawing. The estimate embraces the following materials in place in the works, which are necessary to complete the jetties, two feet above high tide, from each shore of the river to the fifteen-foot contour curve on the outer face of the bar. It includes fifty per cent. for settlement and contingencies. The total length of the two jetties will be three and one-half miles :

#### ESTIMATE.

425,000 cubic yards of mattress-work, \$2.25.....	\$956,250
90,000 cubic yards of stone ballast and riprap, \$6.00.....	540,000
864,000 linear feet of piling, 20 cts.	172,800
240,000 feet, board meas. of lumber, \$20.00.....	48,000
	<hr/>
	\$1,717,050

The mattress foundations of the sea-ends of the jetties are 250 feet wide, and a similar width is deemed necessary in the line of the south jetty where it crosses the south channel near the main shore.

I have not deemed it necessary to make an instrumental survey of the bar, as it would involve considerable time and expense.

The surveys I have consulted are as follows :

1st. A Spanish chart, by Mariano de la Rocque, 1771.

2d. A comparative chart of surveys, by Lieut. T. A. Cravin, U. S. N., asst. 1853, and S. D. Trenchard, U. S. N., asst. United States Coast Survey 1857.

3d. United States Coast Survey preliminary chart, 1856.

4th. Sketch of the bar, February, 1873, furnished by the United States Light-house Board.

5th. Sketch of the bar, February, 1874, furnished by the United States Light-house Board.

6th. United States Coast Survey chart of St. John's River, 1878.

I am much indebted to Dr. A. S. Baldwin, for valuable and pertinent information, and for the loan of several instructive charts, reports and books relating to the problem under consideration. This gentleman has given many years to the study of the subject, and has brought to the investigation of it a large amount of scientific research aided by close observation of the phenomena presented.

I give in his own brief language what he deems the chief cause of the shifting channels across the bar, and the reason of the river discharge being unable to maintain a single channel of greater depth and stability. Dr. Baldwin says:

"Owing to their proximity, difference in volume of water, and sources of supply of the respective streams, there is an interchange of water between the St. John's River and Fort George inlet, producing cross currents, quite detrimental to the free and normal discharge of the waters of the river, through a direct and unshifting channel to the sea. To remedy this condition of things, the cause of abnormal action must be removed.

"The closure of Fort George inlet, or the diversion of its waters through Haul-over Creek, enlarged so as to give passage to them into the river above its bar, so as to cause a commingling of the waters of both streams inside of the bar, instead of an interchange outside, has appeared to me to promise a successful result by removing the cause of cross currents which now interrupt navigation and interfere with the free discharge of the river over the bar.

"The momentum of force of current due to its large volume will enable the

river to open and maintain a channel sufficient for all present or prospective wants of commerce, provided this water can be kept in a concentrated stream, and my opinion has been that if the deflecting influences of the inlet could be removed, the stream then, would not be so liable as now, to be divided into numerous channels; but the waters would then be disposed to concentrate into one stream, having sufficient power to sweep out of its pathway all obstructions to its free passage to the sea, without assistance from artificial appliances to either side of the channel, because I have attributed to the cross current or see-sawing notion of waters across the north shoals, between the river and inlet at different times of tide, a prominent part, and the principal instrumentality in shifting the banks of sand and preventing the river from having any permanent and well-defined channel."

The deep water in front of the beach seen on United States coast survey charts, between the mouth of the river and the inlet, shows the existence of such interchange of waters as Dr. Baldwin refers to, as a result of the difference in time of the tide action in the inlet and the river; and I think it is quite possible that some improvement of the bar channel might have resulted from the carrying out of his suggestions, but not sufficient to meet the wants of commerce. It is, however, very evident that a line of works nearly one and three quarter miles long, transverse to such currents as may be due to the cause assigned, would completely interrupt them and prevent their evil effects.

In addition to the plan of improvement recommended by Dr. Baldwin, Lieutenant (now general) H. G. Wright, United States engineer, recommended in 1853 the construction of a single pier on the north side of the channel. The length and proposed location of this pier I have no information about. Single piers have been applied to drift bars in tidal and non-tidal waters with benefit, but the superior advantage of protecting the channel by parallel piers or jetties has been so abundantly demonstrated within the last twenty-five years as to leave no question about the propriety of applying them in this case. They have

been applied at the mouths of many rivers on the Baltic and the European coast and on the upper lakes, with marked success. The engineers who oppose the jetty system of improvement at the present day, I believe, have confined their objections to its use, entirely to delta forming rivers, and have based their predictions of its failure at the south pass, on the fact that the Mississippi discharges an immense amount of sedimentary matter, which they asserted would cause a rapid re-formation of the bar, immediately in advance of the jetties. This conviction on their part was strengthened by the belief that no littoral current existed there to sweep away this large discharge of sediment. They claimed that the great success of the system was due to the fact that the rivers whose bars had been deepened, were comparatively free of sediment, and that the outer face of the bar was swept by a littoral current. As both of these conditions exist at the St. John's bar, the recommendation herein made to improve it by jetties will doubtless be cordially endorsed by them; while it cannot, I am sure, fail to meet the approval of those engineers who advocated their application to the bar at the mouth of the Mississippi. Their success there, has only confirmed the fact that the system is equally applicable to either delta, or drift bars. The present Chief of Engineers United States Army declared, in 1875 in his annual report, that the jetty system had never been applied to the bar of but one delta-forming river (the Rhone), and that it had been a failure there. This has been publicly declared to be a mistake by Col. W. Milnor Roberts, C. E., who visited the mouth of the Rhone for the express purpose of examining into this very question. He was accompanied by several of the members of the United States commission of engineers, who afterwards reported, in 1875, in favor of applying the system at the mouth of the Mississippi, Col. Roberts has stated the fact, which I and other engineers, who have visited the mouth of the Rhone well know, namely, that the jetty system never was applied there at all. Dykes were built in the river mouth to close several lateral outlets and cause the river to discharge through

one mouth only, but these dykes were never extended out into the sea over the bar to deep water, as is proposed for this bar, and as was done at the south pass, at the Danube, the Dwina, and the Maas, all of which are delta-forming rivers. The dykes at the Rhone were never nearer than seven-eighths of a mile from the crest of the bar.

To confound anyone who still persists in declaring that the jetty system failed at the Rhone, it is only necessary to ask him to point out among all of the many successful applications of the system, one single instance where the jetties are not built out in the sea across the bar to the deep water beyond, and then ask him to state if those at the Rhone were ever built out on to the bar at all.

As the jetties at the ship canal at Amsterdam and those at the Maas, besides innumerable others on the Atlantic, have proved their ability to withstand the severest ocean storms, it is scarcely necessary for me to advance any arguments to show that the proposed works can also be made thoroughly permanent.

The importance of improving the St. John's bar as a matter of national interest will scarcely be questioned in view of the advantages it offers as a naval station on our south Atlantic coast, and as a harbor of refuge.

The delightful climate of Florida, the ease with which many semi-tropical and remunerative products are reared, such as sugar-cane and cotton, and its adapt-

ability to the production of oranges, lemons, figs, dates, bananas, peaches and berries of the finest qualities, is rapidly attracting an industrious and energetic population. Its vast forests already furnish important shipments of lumber, tar, pitch, turpentine and resin, and its gardens furnish to the north large quantities of vegetables, melons, etc.

Notwithstanding the immense disadvantage of the bar at the mouth of the St. John's, the shipments of lumber in 1877, from Jacksonville, amounted to 40,000,000 feet, on which a freight was paid \$1 per 1,000 higher than on that shipped from Brunswick and Fernandina. In this one item alone it will be seen that the bar has cost \$40,000 per annum in extra freights. The vessels leaving port are frequently detained for days, and even weeks, at the bar, waiting for favorable tides and deeper water, at a large aggregate cost for demurrage. This is estimated, by intelligent and well informed parties, to cost the commerce of the St. John's not less than \$100,000 additional per annum.

In consequence of the delays at the bar the clearances at the custom-house, at Jacksonville, have steadily declined from 80,798 tons, in 1873, to 39,681 tons in 1877.

The river tonnage consists of thirty steamers, navigating about 400 miles of the St. John's river, and its branches.

For these interesting statistics I am indebted to Mr. M. W. Drew, of Jacksonville.

## THE APPRENTICE IN THE PATTERN SHOP.

By GRAHAM SMITH, Past President of the Liverpool Engineering Society.

WHEN it is considered that no engineer or architect is properly qualified to design cast-iron structures without having a definite idea of the manner in which patterns are constructed and castings made we feel that it is unnecessary to apologise for introducing this subject to our readers. This craft rightly takes a high position among the trades. To be a good pattern-maker demands no ordinary degree of intelligence, the power of skillfully handling tools, and work both

of a manual and mental nature. It behoves young men therefore on entering the pattern-shop to respect and appreciate at their proper worth the men following this calling. So far as work is concerned the article pupil or ordinary apprentice ought to make himself subservient to the foremen and journeymen with whom he may come in contact.

On entering the shop the new apprentice as a rule will be placed under one of the best men and expected to work in

accordance with his direction. It is to the interest of the pupil to do all in his power to command the respect of this man, whom it must be remembered is paid by his employers to do his day's work and not to teach the apprentice. The latter must therefore make up to him by his services for any loss of time which may be occasioned in teaching him how to handle his tools, and how to become generally acquainted with the routine of work. This is necessary in order that the journeyman may show as good a day's work as other men who are unburdened by the charge of an apprentice. There are many little duties which done spontaneously tend to harmonize the relationship existing between journeyman and apprentice and which with a little watchfulness and tact may be performed in a most gracious manner. Screws, nails, or sand-paper may be required from the stores, or the glue-pot may require reheating. These and numberless other matters of a like nature should be watched for and performed with alacrity and good-will. It is useless for the apprentice to pretend that he is above these minor duties, for as a matter of fact it will be some little time before he is fit to perform others of more importance. He may rely upon it that as soon as he is competent to do work requiring skill and care, the journeyman will not fail to avail himself of his more developed capacities and find some other means of getting his screws or nails. It is to the latter's interest to do so, for if the work is being performed by the "piece," his money-earnings will be larger, or if as is more often the case, he be working "day-work" he will make a greater show for his time by employing his apprentice to the best advantage. The apprentice will not only be indebted for his teaching but he will often require the use of tools which it would be out of the question for him to purchase. A pattern maker's tools are his idols, and one of the first duties the tyro must learn is to return all tools to their owners properly sharpened and ready for immediate use, and above all things he should be careful not to leave them kicking about his bench after having made use of them. A good workman always keeps his tools sharp and otherwise in a proper condition.

A few pounds judiciously expended

will purchase the tools that an apprentice is likely to require, but of course if he purposes to become a journeyman, he must add to this stock from time to time, and as not unfrequently happens it may become in time a most valuable collection. The following will possibly be found sufficient for any one who purposes remaining but ten or twelve months at this class of work:—1 cross-cut saw rather widely set so as to be useful for all purposes, 1 tenon saw, 1 trying plane, 1 jack-plane, 1 smoothing or hand-plane, 1 rabbit plane, 1 spokeshave, 1 set of chisels, 1 set of inside and outside gouges, 1 two-foot rule, 1 oil-can, an oil-stone for sharpening his flat tools, and two or three finger-slips for gouges, a pair of tradesman's compasses, inside and outside calipers, and one or two squares. The turning tools he may for the most part manufacture by grinding down old files. There are other tools of a more costly nature the use of which he will frequently require, such as a brace and bits and "hollows and rounds" for working rounds and fillets, but if he ingratiate himself by becoming and gentlemanly behavior into favor with the men he will experience no difficulty in borrowing these whenever he may wish to do so.

The apprentice should early learn not to be disheartened by failures. It is only natural that after six months he should turn out very rough work when compared with that of the journeyman of six or sixteen years. He should endeavor, however, to make his work as nearly perfection as his abilities will allow, and should on no account try to polish up bad work with sand-paper, or to cover up its imperfections with putty or paint. A good workman seldom employs sand-paper, except when stretched over a cork just to give a finishing touch to the various portions of the pattern before fixing them in place. Under any circumstances it should be used sparingly, and only after the work has been properly shaped with the edge tools. Nothing looks more slovenly than to see ill-finished work sand-papered and put-tied. The apprentice before actually commencing to make patterns must thoroughly understand and have a just conception of the manner of putting the patterns in the sand and getting them out again. On starting to make a pat-

tern his first question to himself will then be, how will it be best to mould this? And the answer much governs the form the pattern should take. It requires great care on the part of the pattern-maker in selecting the proper course, as after the pattern is made the moulder seldom has any choice in the matter.

It is quite impossible here to describe the method of proceeding with complicated forms, but it may nevertheless be well to say something of a simple example, and from it endeavor to point out how to proceed with those of a more intricate nature. Let the example be a simple round cylinder with a hole through its center. It is at once evident that were it not for the hole the pattern might be cast by employing two boxes and making the parting in the sand so as to divide the cylinder into two equal portions, thus leaving an impression of half the pattern in each box. The hole through its center cannot be moulded in this manner. This brings us to the consideration of the question of "cores." Two small circular pieces termed "prints" are placed on the pattern in the position of the extremities of the required hole. These leave their impression in the sand so that a core may be laid in. A core consists of sand moulded to the required shape of the hole, so that on putting the boxes together we have the hollow cylindrical mould with a core of sand running through its center of a diameter corresponding to that of the required hole. The metal being run in and the casting cooled down, it is only necessary to knock out the core of sand and the cylinder is complete with the hole through its center. This is the simple principle on which the most complicated forms are obtained. The interior of a locomotive cylinder and the intricate steam and exhaust ports are taken out in much the same manner as that just described. Small cores are usually made in boxes of wood in which the sand is moulded to the required form and then baked in an oven specially constructed in every foundry for this purpose. Large cores are made in various other ways but these must be seen to be understood. The apprentice will do well to devote any spare time he may have to watching closely foundry operations. He will then become conversant with the practice of this department and

learn to make his patterns so that they may be easily removed from the sand.

In making patterns the drawings must not be followed implicitly. Sufficient "draw" must always be put on to enable the patterns to be got out of the sand. Slightly over one-sixteenth of an inch in a foot is generally sufficient for this purpose, but when the exact form of the casting is not of great importance, or when portions of prints are to be filled up by the moulder, more may be given with advantage. Those portions of the castings which have to be tooled must have additional metal put on in the pattern, to be afterwards taken off by the machine. Patterns must likewise be made somewhat larger than the finished casting in order to allow for the contraction of the material in cooling. Experience teaches the amount to be allowed for each description of work, but one-tenth of an inch to the foot is generally considered to be about the proper thing for cast-iron. With steel and brass a somewhat greater contraction takes place and so an allowance of about 3-16ths of an inch to the foot becomes necessary. The shaking necessary to loosen the pattern in the sand previous to its removal somewhat increases the size of the mould, and this is usually sufficient when dealing with small work to provide for the contraction of the material in cooling, so that patterns of small size are as a rule made as nearly as possible in accordance with the dimensions shown on the drawing.

The wood mostly employed in pattern-making is yellow pine. It is a soft, easily worked, straight-grained timber. Thoroughly seasoned wood should alone be employed in every portion of a pattern. If this fact be overlooked the pattern will shrink and twist and it may become perfectly useless. For small work and where a large number of castings are required to be made teak, mahogany, or bay-wood, and plane-tree are generally the woods used. Patterns of this nature are usually coated with a varnish made by dissolving shellac in spirits of wine or naphtha. Yellow pine patterns when made of properly seasoned wood ought to be painted. This prevents them from absorbing the moisture from the sand while in the mould and preserves them against atmospherical influences. Foun-

dry operations are likewise facilitated as when treated in this manner they part from the sand more readily. If an extraordinary large number of castings are required from the same pattern, soft white metal is employed for small cast-

ings, or a casting is taken from the wooden pattern if the form will admit of it, and afterwards used for subsequent castings. In this case the allowance for contraction on the wooden pattern must be double that given in this article.

## TIMBER RESOURCES OF TURKEY IN EUROPE.

From "Journal of Forestry."

A FRENCH writer, M. Bricogné, has lately been at the pains to collect a large amount of information relative to the forest products of the Ottoman Empire, which is not without interest at the present moment.

Availing himself of the reports of M. Bzrozonski, late chief inspector of forests in the *vilazet* of the Danube, and other presumably reliable sources of information, M. Bricogné shows that the reported wealth of European Turkey in timber—like other reports circulated from time to time respecting that unhappy country—must be regarded with a more than ordinary share of reservation. The natural capabilities of the country in a forestal point of view are undeniable. Its diversity of surface, productive soil, and semi-peninsular position fit it to grow the finest timber in Europe.

Noble forests have been, and in some places still are; but, with few exceptions, the hand of the spoiler is everywhere seen. Ignorance and greed have destroyed Nature's gifts; and where valuable timber yet remains, it is, as a rule, because it is too inaccessible to be worth the trouble of reaching it. Differences exist between the several *vilazets* or provinces, but the remark applies with more or less truth to all.

Bosnia (including Herzegovina) was of yore one vast forest, and though sorely despoiled, still contains some of the finest oak and beechen woods in Turkey. Bosnian oak, mostly the peduncled and sessile-flowered kinds, with a sprinkling of *Q. Agilops*, is not suited for shipbuilding, but splits well. There is a considerable export from the province, chiefly in oaken staves, deals,

and firewood, the latter mostly beech and birch. Most of the stave-wood goes to Marseilles; the deals into Russia. During the six years 1868—1872, thirty millions of oaken staves, averaging 38 inches in length,  $4\frac{3}{4}$  to 6 inches in breadth, and  $\frac{3}{4}$  to  $1\frac{1}{2}$  inches in thickness, were thus exported. Large numbers of telegraph poles and railway sleepers are also cut, and over 18,000 tons of wood are annually consumed on the line of railway from Salonica as fuel, wood being found cheaper than imported coal. Bosnia is rich in surface minerals, and amongst other causes of sylvan mischief are mentioned what are known in France as "Catalan forges," a primitive mode of iron-smelting, which not only consumes much wood, but occasions frequent forest fires.

Of Albania little is known. It has fine forests of beech and fir, which are very inaccessible, and the export of timber is forbidden on political grounds.

Thessaly and Macedonia in bygone days supplied the dockyards of Salonica, and entire fleets were built of oak thence brought. The demand continues, but the supply has fallen off, and here, as in other parts of the world, the choicer descriptions of naval timber are no longer procurable. These woods still furnish a variety of forest products, from holm-oak charcoal to the tallest masts. Amongst the industrial establishments located there are mentioned a large manufactory of farm implements and numerous saw-mills in the mountains. Forests of conifers clothe the mountain sides, and about Mount Athos are noble forests of oak and chesnut, described a good many years since in that very entertaining work, Curzon's "Visits to

the Monasteries of the Levant" (1834), and which are still nearly untouched. They belong to the mountains, and some of them are said to date from the time of Constantine the Great (A.D. 313). Bulgaria, in the Middle Ages a vast forest, of which traces were still visible fifty years ago, now scarcely possesses wood enough to supply the inhabitants with fuel. As an illustration of the rapidity with which the work of destruction has gone on there of late years, the forest of Deli-Orman is mentioned. At the beginning of the present century it covered an area of 2,500 kilometers, and contained some of the finest oak in Europe; now it is reduced to between 30,000 and 40,000 *hectares*, full of clearings and mangled trunks. In Bulgaria, more than anywhere else, the effects of disafforesting are felt in the increased severity of the winters and the increasing frequency of droughts.

The *vilazet* of Adrianople—the ancient Thrace—appears never to have been much wooded; but it was the most populous and best cultivated part of the Byzantine empire. Then and afterwards, so long as agriculture flourished, the timber was respected; when it declined, the woods began to suffer. It is at present irregularly and sparingly wooded, but there are some fine woods of oaks, beeches, pines, and firs. The markets for the timber are along the upper course of the Maritza, in large towns like Adrianople, Tatar-Bazardjik, &c., and in Egypt and the Archipelago.

The *vilazet* of Stamboul at present contains but little timber, although it is said that at the beginning of the century the environs of Constantinople presented a fine growth of forest, which now no longer exists. Everywhere the destroyer has been at work. Even the forest of Belgrade, which encloses the reservoirs for the supply of the city, has been reduced within the last thirty years from 12,000 *hectares* to 7,500, one-third of which is clearings.

So far as authentic data are procurable, it appears that Turkey in Europe must still contain at least 1,425,000 *hectares* (three and a half million English acres) of forest and woodlands.

The varieties of timber are not numerous, but what there are are valuable. As a rule, the larger flora of European

Turkey differs but little from that of Western Europe, and amongst the numerous shrubs which flourish luxuriantly on low warm sites, and which include the myrtle, citron, orange, olive, rose, &c., are very few but may be found in similar localities in the South of France.

Forest vegetation exhibits four zones, which now are very imperfectly defined, varying much in their vertical limits in different localities, and even in the same locality with different aspects.

1. The oak (chiefly the peduncled and sessile-flowered varieties) and the chestnut rise, the former to an altitude of 3,200 feet, and the latter to about 2,600 feet.

2. The beeches are found, according to the locality, up to altitudes of 2,000 to 5,000 feet.

3. Resiniferous species—firs, larches, scarlet and Austrian pines, &c., are generally found between 2,600 and 6,200 feet above the sea level. In the Despotodagh—the ancient Rhodope—are still large forests of pines intermixed with firs, crowning the highest summits of Olympus, as probably they did when Euripides applied to it the epithet "many-treed." Here, 6,700 feet above the level of the Ægean Sea, is the highest woodland observed in Turkey in Europe.

4. The evergreen oak, the Judas tree, and a variety of noble arborescent shrubs, mingled with some woods of Aleppo pine, cover (where they have been spared) the low hills bordering the Ægean and part of the Sea of Marmora. On the Black Sea shores peduncled and sessile-flowered oaks are found at all altitudes, coming down nearly to the water's edge. The oak, the tree *par excellence* of the Balkans, within its own vertical limits may be said to be the predominating forest growth everywhere in European Turkey.

Several distinct classes of property are recognized in Turkey in respect of standing timber.

First, there are the woods known as *korous*. These belong to private persons or village communities, both the land and the timber on it being private property.

Next come the State forests properly so called, which have been specially as-

signed to the use of some particular branch of the public service, as the Navy or the Ordnance. Then there are the *baltaliks*, woods of which a right of usufruct belongs, by ancient custom, to particular villages, the land remaining the property of the State. A sort of semi-proprietorship exists in the case of these *baltaliks*, as the users have a legal right to prevent strangers cutting wood in them, although they have themselves no right to sell or even to clear the ground.

Intermediate between public and private woods come those known as *vakoufs*, which have been left at some time or other for the use of religious foundations, and the management of which consequently rests with the *evkaff* or administration of mosque property and charitable trusts, which receives their revenue and defrays the cost of management.

Lastly, there are the public forests, which virtually belong to no one, but of which every one makes unrestricted use as though bent on their annihilation at the earliest possible moment.

According to both the letter and the spirit of the old Ottoman law public forests (*djebel mubah*) could only exist where the land was utterly valueless. The remoter parts of mountains, the face of cliffs, inaccessible peaks, and the like, alone were to be thus regarded as a sort of "no man's land," as the Arabic root of the word *djebel*, denoting a rugged mountain side, testifies. But in practice, particularly of late years, it has not been so. Wherever forest land, not being private property, has proved easy of access, or facilities have offered for its destruction, there both land and timber have been treated as *djebel mubah*, and worked accordingly. And it is a significant fact that wherever *djebel mubah* is recognized agriculture declines and disappears, leaving the population dependent for existence on the forests they are doing their best to destroy.

The Forest Department, which figures in the Turkish Budget of 1875-6 for a sum of £161,000 sterling, has proved wholly inadequate to meet this evil. The causes are too deeply seated. The disappearance of the flocks, the folding of which formerly provided for the amendment of the fields, the decline of tillage under the ever-increasing burden

of taxation, the ignorance and obstinacy of the peasantry (in which respects the Christian populations stand conspicuous), not to speak of the squabbles between the *erkoff* and the officials of other departments, and the utter apathy and indifference of the Government, all have contributed to the results.

Private woods, as the *korous*, it should be said, are generally well preserved; and there appears reason to believe that with adequate forest management much valuable timber might yet be saved in various parts of the country, and, with the aid of improved communications, be turned to account.

However this may be, of the present state of the timber resources of Turkey in Europe there can be no doubt. The popular notions of forestry there prevailing may be summed up in the pithy words of a recent writer, who refers to the climatic changes the country has evidently undergone owing to disafforestation:\*

"The destruction is truly pitiable, and the plains and low hills are for the most part denuded of trees. If wood is wanted for a fire, the nearest trunk is mangled with an ax to provide it; and if there is a ready sale for the wood, down come the trees wholesale, without a thought of the future. The idea of planting trees never enters into the head of Turk, Greek, or Bulgarian. It would be a present outlay for the benefit of posterity, which would appear to every one as the act of a lunatic."

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SUPERSATURATED solutions of many salts often spontaneously deposit crystals, which are less hydrated than the common salt. In many cases before the point of spontaneous deposit is reached, a crystal of the less hydrated form will start the deposit. In such cases a brisk friction against the walls of the vessel will often produce crystallization. D. Gernez has observed three modes of this mechanical action: (1) the simple production of the least hydrated crystals; (2) the production of the most hydrated crystals, in solutions where the other hydrate would form in contact with a crystal; (3) the production of either salt, under different degrees of friction.

\* Baker's "Modern Turkey in 1877."

## EMERY AND CORUNDUM WHEELS.

By ARTHUR H. BATEMAN, F. C. S.

From "Journal of the Society of Arts."

THE two great divisions of the metal industry are the elimination of metals from their ores, and their working up into forms for use.

The first class involves highly scientific processes chiefly carried out by unskilled hands, the second necessitates individual skill on the part of the workers.

The chief means of working up metals are, casting, forging, and shaping, both of the former requiring more or less of the latter, and in each the removal of superfluous metal plays an important part. This is effected chiefly by files and chisels to some extent, and in some branches also by grindstones.

A file is a specially prepared tool, of which only a very small per-centage can be considered to be practically useful. A chisel is the same, and requires constant attention to its small cutting edge, the great bulk of its weight also being useless for its actual work. A grindstone, reduced to its elements, is composed of a large number of particles of natural material, mostly silica or its combinations, and the individual grains of which are irregular in hardness, shape, and size, mostly smooth and comparatively rounded. It will attack hard metals, which the file and chisel will not, but, owing to the difficulty of securing real homogeneity, it cannot with safety be run at a speed requisite to utilize its full cutting power.

For rapid working of hard materials whether metals or stone, &c., something harder and more lasting than these tools is required, and for many centuries natural substances have been used to assist.

It is probable many of the ancient gems now in existence were cut by the help of emery powder and to this day the Indian and Turkish lapidaries use a wheel compounded of shellac and this material rotated with a drill bow. This remarkable substance is often spoken of as steel filings, or as an oxide of iron, but is really a mixture of corundum and oxide of iron. Corundum itself

is almost pure alumina with a little silica; and, in its purest form of all, slightly tinged with iron oxides, is sapphire and ruby; in a less pure state, and with traces of various foreign substances, it is of commercial rather than fancy value, and is found in unimportant quantities in various parts of the world. It is also known as adamantine spar. Comparatively recently large deposits of corundum were ascertained to exist in America, and it is a somewhat singular fact that this took place almost simultaneously with the discovery in 1847, by Dr. Lawrence Smith, an American geologist, of the now famous Turkish deposits of emery. The former, however, was allowed to lie dormant until 1865, while the latter, being brought to the notice of the Government, were almost immediately utilized. Further investigation showed these deposits to be of considerable magnitude; the chief are near Smyrna and the ruins of Ephesus, also in several islands of the Greek Archipelago, notably Naxos, from a promontory in which island—Cape Emeri—it takes its name. Deposits of little or no commercial importance are also to be found in Jersey, Spain, Poland, Saxony, Sweden, Persia, and the Andes of South America. Quite recently, it is stated, important discoveries of emery in a granular form have been made at the Adirondacks on the North American Continent.

Although called mines, the emery workings are really on the surface only, or very little below the surface. The dark red color of the ground affords a pretty sure indication of its presence, but steel rods are stuck into the earth and a practised eye soon detects the presence of emery rock by the marking on their points. The mineral occurs chiefly in large masses, sometimes susceptible of rough breaking, at others resisting blows. In such case, a fire is lighted round the refractory lumps, and on cooling, after some hours of heat they will often be found more amenable to treatment. Blasting is seldom practicable, from the difficulty of drilling

holes. As transport to the sea is solely attainable on the backs of mules and camels, a weight of about 100 pounds is considered the practical limit for individual lumps. The Turkish and Greek Governments sell the monopoly of raising emery rock, and for many years nearly the whole has been controlled by English capitalists, in fact, until recently a company known as the Levant Company have had the practical control of the market. During the last few years there has been more independent working, and the supplies have been large, but at the same time, a greatly increased quantity of inferior rock has come to England. It is chiefly sent over as ballast; freight thus is an insignificant item.

The specific gravity of emery ranges from 3.75 to 4.28, and may be taken to average 4.0; the color varies from dark grey to black, and is no indication of value. Owing, however, to general misappreciation of this fact some English firms color their crushed emery to a uniform tint, and uncolored emery is often unsalable, and put down as bad or impure by buyers used to a particular shade.

Nothing is done in the producing beyond the rough sorting and breaking into lumps under the above limit of weight. On arrival in this country the emery crushers submit it to treatment, to render it available in manufacturing processes. There are but few firms in this trade—until within a few years since only four or five, but at present more are engaged in it. As a rule, emery crushing works are not shown in operation. Several processes are employed, each being held to possess its own special advantages. First the rock is smashed into pieces about the size of walnuts, by passing again and again through Blake's or other crushing machines; it is then either stamped with stampers, passed between chilled rolls, or through grinding mills, the latter being circular cast-iron plates with upright lands six or eight inches high. These wear away by degrees as may readily be believed, but last from four to six weeks. The jaws of the crushers last from two to three weeks, stamps last longer and work slower; of the life of chilled rolls I have no information. Microscopic ex-

amination of crushed emery shows, not only the distinct presence of the two substances, corundum and oxide of iron, with a certain per-centage of quartz which is often mixed with the emery rock, and a trace of iron from the machines, but also in many instances iron slag and other similar substances used as adulterants. It is by no means certain that some such substances may not be a positive improvement in some respects, as causing a freer cut; but in this case it is certainly desirable that any such admixture be made by the user and not by the crusher. All makers of solid emery wheels guarantee that they use pure emery, but, as only one firm crushes its own rock, the microscope should always be used to see that what is bought as pure emery really deserves that name. The microscope also shows that there is little, if anything, to choose between the grains produced by rolling, crushing, stamping, or milling, as far as regards sharpness of angle. The great points seem to be attention to quality of rock, careful removal of bad pieces containing foreign matter, and accurate sifting.

By the kindness of Messrs. Acton & Borman, who have large emery crushing mills, I am enabled to show a very good selection of emery rock, good, indifferent and bad.

After the emery has passed through the machines it is sifted through a series of sieves ranging from 6 to 100 linear meshes to the inch, and all pieces larger than the former size are returned to the machines for further crushing. The process is an eminently dusty and disagreeable one, and from the beams, roof, and upper parts of the crushing shops is collected what is known as flour emery which has deposited from the atmosphere. Finenesses of 120 and even 140 are thus obtained. Still finer grades are, however, required for polishing plate glass, opticians' work, &c., and for this the very beautiful process of elutriation, or washing over is employed. A dozen or more metal cylinders, three or four feet high, and ranging from three inches to 36 or 40 inches in diameter, are connected near their upper edges by pipes; the whole series is filled to the brim with water, emery and water well mixed are introduced into the smallest vessel; the

water of course flows out at the opposite pipe to the next, and so on through the whole series. The coarsest powder falls during its three inch journey across the first cylinder, the next coarsest through its four inch, then its six inch, and so on until at last practically pure water flows from the exit tube of the last 40 inch vessel. After a time the process is stopped, the material allowed to subside, the superincumbent water decanted off and the deposited emery removed and dried. This process is carried out by the users, not by the crushers.

The chief use to which powdered emery has been put is, in its raw state, in metal workshops, also for glueing on to sticks of the shape of files; for use with lead laps or polishing wheels, and glued to paper and cloth, in which form it is generally used by mechanics, wrapped round a stick or flat piece of wood. Paper seems better for this purpose than cloth, though the latter is preferable where it is used without such support. Envelopes of emery paper with shaped sticks have also been patented, but have never come into general use. Emery has also long been extensively used for buffing and polishing, by covering a wooden disc with leather, glueing fine emery on to the surface, and rotating it when dry at a high speed. The yielding nature of the latter causes this to be absolutely unsurpassed as a polishing medium for hard metals or other substances.

In 1842, Henry Barclay patented a process for a solid emery wheel, using an equal part of Stourbridge clay and emery, pressing the wet mixture into moulds, and subjecting it to a bright red heat. This is said to have given a really efficient wheel, but it does not appear to have been practically worked, as only small discs, say eight or nine inches diameter, could be made, owing to the difficulty of avoiding cracks and distortion in the process of firing. It is satisfactory to know that the actual father of the modern emery wheel was an Englishman, although the development of the idea has certainly taken place on the other side of the Atlantic; and we are now appearing to be copying our American cousins in our tardy adoption of a *bona fide* English invention. About ten years later, I believe, efforts were made to introduce and extend the use

of solid emery wheels by Mr. (now Dr.) Anderson, then of Woolwich Arsenal, but it has only been during the last five or six years that anything approaching to general attention has been paid to the subject.

Five years ago, there were many makers of solid emery wheels in America, but only about four in England; at the present moment there are double this number, and one of the leading American makers is personally represented in this country. Notwithstanding the depressed condition of the metal trade, the sales of most of these makes have probably something like doubled annually of late, showing that the subject is one assuming real commercial as well as scientific importance, and worthy of the attention of the members of this Society.

An important peculiarity of emery or corundum is its extreme hardness. The diamond is the hardest substance in nature: absolutely pure corundum, in the form of sapphire, and ruby comes next; the commercial variety is scarcely inferior, and closely approaching is emery; but a still more important feature of the latter substance is its tendency to break with a rough surface, or what is known as conchoidal fracture. However finely the rock may be crushed, this roughness still exists, and even flour emery, examined under a moderately high power, is found to sustain this peculiarity, and to present a series of sharp angles and points. As an individual grain wears smoother by friction, it still, to a great extent, carries out this disposition, so that a disc or wheel made of grains of emery, if properly cemented together with a binding material that will not melt and form a skin on the cutting surface (as is sometimes the case), presents absolutely a constant succession of fresh cutting surfaces.

The question has been asked, whether a disc of solid emery rock would not be better than crushed grains cemented together again. The answer is obvious, that the vast amount of rough surface present in the built-up wheel would be absent in the solid mass, quite apart from the extreme difficulty of manufacture.

The peculiar property of conchoidal fracture above referred to, as possessed by emery, is not shared in anything like

an equal degree by corundum, and although in crushing this latter mineral many sharp points are obtained, there are also considerable plain and curved surfaces, never seen in the somewhat less hard emery. The result is as might be anticipated—the process of manufacture being the same, a disc of corundum will, under similar conditions of running, do as much or perhaps more work than a similar disc of emery, but it will heat the metal much more, because, while emery with its sharp points cuts its way, corundum with its harder but smoother faces tears its way into the work. For certain purposes, where it is possible to run in a constant stream of water, corundum wheels appear superior to emery; but for the general run of engineers' work, which is certainly on the whole done best dry, for tool grinding, and indeed most other purposes, our English experience is so far vastly in favor of emery over corundum wheels. A common form of corundum is that known as "ruby," this is found in small grains averaging about 24 grade. It is water-worn and rounded, and breaks with comparatively smooth faces. This material, crushed, however, makes very good fine wheels.

The natural corundum of North America which is much rougher in grain has been specially worked up by Messrs. Morton, Poole, & Co. of Wilmington Delaware, with the special object of trueing chilled rolls. I am not aware of the process used, but am informed that extremely good results have been obtained. This same operation is, however, conducted in Belgium, Germany, and elsewhere, with emery wheels, with entire success.

The microscopic projection on the screen of actual grains of emery and corundum clearly shows the peculiarities of the respective substances; and to emphasize the distinctive characteristics of numerous small points *versus* larger points and wide planes, I add projections of sands, crushed grindstone, flint, and glass. You will observe at once that the sharp points of the latter substance must give good work until broken off, when the cutting power will vanish. You will also note the smooth and round appearance of the grains constituting the ordinary grindstone.

These projections indicate the probable relative cutting power of the various grains available for the manufacture of grinding wheels. It now remains to consider the best means of agglomerating these grains into a solid mass and utilizing the same.

It is manifest that, by the adoption of the circular form, steam power may be used instead of manual labor, and if a cement of sufficient strength be employed to withstand the centrifugal force (which increases as the square of the velocity), we have the remarkable result of, on the one hand, a steel file moving at the rate of about 60 feet per minute, driven by a man whose arms grow tired, and the tool itself useless when under 5 per cent. of its weight is used up, and on the other, a circular file much harder than steel, whose cutting face never grows dull, driven by a steam engine, which never gets tired, at a speed of 5,000 feet per minute, and which can be used up to the extent of about 90 per cent. of its original weight. Small wonder, therefore, is it, that rapidity, economy, and precision are obtained by this new tool, and that it has shown rapid growth since it first obtained a footing in English workshops.

Circular steel files (of which a specimen is on the table) have been tried more than once, run on a lathe or other rotating spindle; but their high cost, and the difficulty of preserving a flat face during the hardening process, and the small percentage of useful material, combined to prevent them coming into general use.

It may be asked if one half of what is claimed for the solid emery wheel be true, how is it that, instead of a gradual introduction, it does not instantly take its place in every workshop in the kingdom?

The answer is fourfold. 1st, the English workingman (and to a certain extent the master also) is intensely conservative—why should he now use a tool he has done without all his life? 2nd. It is said we cannot be perpetually adopting American "notions"—forgetting this is really an English notion adopted by the Americans, because they have found it to be a real economy, which enables them to positively compete with us in our own markets, in the face of the heavy charge for 3,000 miles of

carriage. 3d. It has already been tried and found a failure—probably put to unsuitable work, something that could not be done any other way, and an expectation formed that the new tool could be used in a moment without practice, condemnation following, because immediate success was not obtained. 4th. A dread, or fancied dread, of the necessary speed—quite oblivious of the fact that our trains run faster, our circular saws run faster, our wood working machines run faster, and that with the proper and ordinary precautions requisite in all high speed machinery, there is no more danger than with many tools in everyday use already.

The novelty of emery wheels has caused the few accidents that have happened to be noised abroad, while those occurring with grindstones excite little attention. After considerable research, I am unable to obtain actual figures on this subject; but there is little doubt in the minds of those qualified to judge that the per-centage (not the actual number) of emery wheel and grindstone accidents, is much in the same ratio as those of railway trains as compared with stage coaches.

It may again be asked, have any firms of repute, after introducing emery wheels, discontinued their use? In some few cases this has been the case, the reason being given that the opposition of the workmen did more harm than the use of the wheels did good; but coupled with the avowed intention to try again later on. On the other hand, the firms who have extended their use of this labor-saving invention, after their first trial, are large in number and an ever increasing quantity. In many shops grindstones have vanished; in others the file bills have been cut down to one-half and one-third; in others, again, work heretofore impossible has been successfully accomplished, and materials hitherto unavailable have become admissible. A file can cut nothing harder than itself, and hard steel and chilled cast iron defy it. These materials are readily amenable to the solid emery wheels, and a new art has sprung up with their introduction—that of shaping dead hard metal either flat or cylindrical, instead of turning and subsequently hardening, the latter process

not infrequently resulting in the destruction of accuracy by twisting and warping. Specimens of such work are on the table.

To the manufacture of a good solid emery wheel three essentials combine—good emery, good cementing materials, and extreme care in their combination. Probably the earliest commercially successful solid English emery wheel was that introduced 16 years ago, under the patents of Cole, Jacques, and Fanshawe, in which the cementing material is that curious compound known as oxydized oil largely used in the well-known linoleum. The cement and emery are intimately admixed, pressed into accurate metal moulds, and subjected to a high temperature under the action of superheated steam. The resulting wheel is remarkably strong and homogeneous, is susceptible of manufacture in very thin discs, being to a certain extent flexible, and although giving off some slight smell in use, is widely accepted as a very valuable wheel. Another form is manufactured with shellac as its binding material, the ordinary smell of this substance being almost overcome by a peculiar mode of manufacture not made public. This process can be applied also to covering light iron pulleys, rims, and plates of metal, and is said to give good results.

A recent introduction to this country is the manufacture of what is known as the Union wheel in America, but is here called the Magnesian, from the fact of the cementing substances being oxychlorine of magnesium. A positive stone is the result, for which enormous inherent strength is claimed, while a low rate of speed is, nevertheless, recommended as the best for cutting. Yet another process is that of Mr. F. Ransome, in which silicate of soda (dissolved flint) being mixed with the emery grains together with a small proportion of free lime and natural soluble silica, double chemical decomposition is set up, resulting in the almost entire change of the three cementing substances into the one insoluble silicate of lime, which binds the emery in enormously strong bonds, the action being facilitated and hastened by the application of gentle heat, not baking as is sometimes erroneously stated. A remarkably strong and

free cutting wheel is the result. Being hard and unyielding, thin discs require considerable care in use, but the inherent strength of the material is enormous, and when sand is used as the base instead of emery a most successful building stone is produced.

Two or three other processes are also used in England, but are not made public. Sample of the wheels referred to are on the table with portions of the majority showing the internal structure of the finished wheels.

On the European continent, besides imported wheels, there are several local makes of varying degrees of merit, but mostly cheap (or rather low priced), and with greatly less cutting power than English and American wheels.

In America, the natural home, at present, of the solid emery wheel, the processes are numerous and the sales very large. The Tanite, now represented in England, has long enjoyed the reputation of being the standard wheel; it is the highest priced; the cementing material is believed to be a solution of leather. The Union wheel (called Magnesian in England) took the Philadelphia Exhibition medal in 1876, and now claims to be the leading American wheel; it is sold in England under the auspices of a highly respectable London firm. Others may also be named; the Northampton, enjoying a good reputation; the Vulcanite, calling itself the genuine and original; the Climax, claiming to be made of American emery, recently discovered in the Adirondacks, and to dispose of a cubic inch of cast iron in 49 seconds; the Vitrified, a porous wheel with a central water supply, the Cosmopolitan, and many more. Each of these wheels—or rather their makers—claim to be positively the best, some advocating high, others low speed, and generally indulging in those little amenities at the expense of their rivals, fortunately more common across the water than with us.

In conclusion, a few practical remarks may be offered. A common delusion prevails that an emery wheel is a tool requiring neither skill nor practice, and it is left to anyone who chooses to work it. The result of this same system, as applied to grindstones, has caused that article to assume the simply disgraceful appearance it often exhibits—antrue,

worn into grooves and hollows, no one responsible for keeping it right, and the result utterly wrong. This system pursued with emery wheels is simply fatal to their chance of success.

Mount an emery wheel on a suitable machine on a ridge foundation (do not put a heavy wheel on a light spindle), run it at proper speed, checking the calculation with a speed counter, keep it always absolutely true with the diamond (a tool not half enough used), press the work lightly on the wheel—"crowding the work," as it is called, heating more and doing less than gentle pressure; appoint a careful man to use it and make him responsible for its condition, allow him a reasonable time to learn and understand a new tool, and one possessing very great and very unusual power, and the result cannot fail to be satisfaction of the highest degree. But set an ignorant or prejudiced mechanic to a badly appointed machine, with untrue wheels, and expect him to turn out as good work in an hour as he does by other means after years of training, and the result, of course, will be disappointment and condemnation of the unfortunate emery wheel.

This may be considered an overdrawn picture; any manufacturer or traveler will tell you it takes place every day. Again, do not commence your emery work by attempting to do something you cannot do with ordinary tools; get accustomed to the new system, and then apply it to the difficult jobs.

Emery grinding can no more be learnt in a day than the proper management of a lathe or planing machine. Further, give an emery wheel a fair chance by mounting it properly (at present engineers will pay hundreds for a good lathe or planing machine, yet grudge twenty pounds for a proper frame for an emery wheel), in short put emery wheels to work they are suited for, be content to spend some time in learning to use them and the result cannot fail to be satisfactory in England as in America.

For ordinary fettling and general rough work, the simplest, cheapest, and quickest way is to hold the work in the hand against the wheel occasionally dipping in water to keep it cool, a good wheel not being prejudicially affected thereby. For tool sharpening and grind-

ing, a small stream of water under some pressure thrown on to the tool is advantageous, but if much metal has to be taken off in consequence of a deep chip, broken point &c., it is generally the quickest plan to ignore the temper, grind rapidly, and then re-temper. For really accurate work, of course mechanical feed is essential; flat surfaces being fixed on the traveling table and traversed under a revolving wheel: cylindrical articles are rotated in a lathe, an emery wheel fixed in a holder in the slide rest, being revolved by an independent strap, and fed against the work to be operated upon. Long bearings are desirable for the high speeds required for emery wheels, but there is no absolute rule as to material; brass bearings work well as do white metal, and considerable success has been achieved by the new bearing called metaline, a method of treating brasses, obviating the use of oil or any other lubricant. Absolute rigidity, firm screwing home of all nuts, &c., are manifest necessities when high speed is employed.

A solid emery wheel does not profess to polish, it cuts; and to polish there is nothing to surpass the old leather buff previously described, the elasticity of the leather rendering a very fine polish obtainable, with little or no signs of scratches; but the solid wheel prepares work admirably for the buff, and enables it to be used only for its legitimate purpose, thus causing it to last greatly longer than if used to rough down as well as polish.

Emery wheels may be improved in the future, but as at present prepared they do extraordinary work; the chief field for improvement is in the mechanical appliances to use them in. If an elaborate and expensive machine is required to actuate and utilize a simple point, it is equally required for this revolving file. Some such exist, and I now proceed to project on the screen representations of some of the more interesting English and American machines.

While the essence of emery grinding is high speed, that alone is not sufficient. I exhibit a plate with half-minute cuts made by  $12 + \frac{1}{2}$  emery wheel and same size grindstone, each running at the same speed (the latter of course carefully protected by large side plates), show-

ing in a remarkable manner the difference in cutting power. The respective wheels that did this work are on the table. The first cut shows little difference; but it will be observed while the emery retains its cutting powers, the grindstone rapidly loses it, until, in the fourth and fifth cut, there is an enormous difference.

I am sure I am justified in saying that the several firms now engaged in this manufacture in England will willingly give opportunity, at their respective works, to any persons here present, or their friends, to test for themselves the statements and claims put forward on this occasion; and finally, I trust that the ventilation and discussion of this subject will lead to the more rapid introduction of one of the most wonderful labor-saving inventions since the practical application of steam, with the desire that our own proud position in the foremost rank of producers of machinery and general metal work, to the benefit of our manufacturing industries and the increased reputation and profit of both employers and employed throughout the British Isles.

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THE first railway opened in Japan was from Yokohama to Tokio, eighteen miles long, of narrow gauge, and with carriages of light construction, similar to tramway cars. The journey from Yokohama to Tokio occupies about an hour. A prolongation from Tokio to Tagasaki is now being surveyed. The Kobe and Osaka line, twenty-two miles long, was opened in 1873, and that from Osaka to Saikio or Kioto in February, 1877. These two are broader gauge, with substantial works, well-built stations, and the usual type of rolling stock. The three have been built and superintended by English talent, and the material and rolling stock came from England. The line from Kobe to Saikio is to be completed by a line to Isuruga. The idea of connecting Saikio with Tokio is abandoned for the present, the Treasury being too heavily loaded, the debt contracted to the date of the report having been 152,000,000 yens, or 836,000,000f. With regard to tramways, a Belgian company is endeavoring to obtain the concession for one at Tokio.

## NOTES ON JAPANESE ARCHITECTURE.\*

By MR. JOSIAH CONDER.

From "The Architect."

IN venturing to accompany several sketches made by me in Japan with a short Paper upon Japanese architecture, I feel in no small measure how imperfect is the knowledge that I have as yet been able to accumulate on the subject. As, however, it is one upon which not very much has been written, especially from a professional point of view, I beg permission to lay before you my scanty notes, hoping for a future opportunity of enlarging upon them after longer and closer observation and more extended travel in the country. The most noteworthy buildings being those devoted to religious purposes, consisting of the ritual of a most complex mixture of faiths, combined with the deification of deceased historical heroes, it is a matter of no small difficulty and research to form a clear analysis of the meaning of their arrangements and peculiarities. There is much to be done at some future time in comparing the forms of Buddhist architecture here with that of India and China. The introduction of Buddhism into Japan from Corea dates 552 A.D., but it remains to be seen how far the religious architecture is a pure imitation, and how far it is a modification of that of China; how far it has been simply copied, and how far grafted on to an original style, or afterwards modified by the inventions of native artists or by religious reformers.

All Japanese architecture, until the employment of foreigners within the last few years, has been, with very few exceptions, entirely of wooden construction. In certain parts of the country, where stone lies to hand in boulders or is otherwise naturally exposed, there are a few instances of its use in the construction of the walls of small houses and simple temples. There is a small temple near Nikko, about fourteen feet square, of which the walls are built of oblong blocks of stone placed upon their narrow ends, forming the whole thickness of the wall, without bond, and hav-

ing all the external joints covered with a large plaster roll to keep out wet. The roof is also formed of large slabs of stone hollowed out on the surface and cemented at the joints in imitation of tiles. In addition to this there are to be seen several stone bridges—large stone walls surrounding the principal cities, solid stone monuments to the dead, imposing flights of stone steps with stone railings leading up to the temples, lamps of stone and bronze adorning the temple precincts, bronze statues of gigantic size; and stone is invariably found employed in the pavement of courts, and as a sub-structure to wooden buildings in order to form a stable and dry foundation. On account of the constant fires which occur in the large cities, particularly during the winter, there are not many of the ordinary street dwellings which have not been repaired or rebuilt within quite recent times. The temples, protected by their isolation and in many cases by thick groves, also many important dwellings set apart by themselves can boast considerable antiquity, but the ordinary domestic and street architecture is of comparatively modern erection. Some of these larger dwellings of the nobles have fallen a prey to treachery and wanton destruction, others have been burnt to the ground through the introduction of English heating appliances into wooden walls without precautions and protection. The Tokio Foreign Office, one of the finest old Japanese buildings in the capital, which was entirely destroyed this year by fire, is said to have been set on fire through a stove pipe running through a wooden wall without any protection whatever. It appears, nevertheless, from such representations as can be found in books, that the arrangements and general appearance of the ordinary houses have not altered since very early times. They are fragile wooden structures, never more than two stories in height. The walls are constructed of a vertical and horizontal framework of posts and beams morticed together, filled in with bamboo

\* A Paper read at the Royal Institute of British Architects on March 4.

laths, laid crossing, bound together, and coated with mud in several layers, being finally plastered over. Sometimes the beams and posts show, being flush with or projecting beyond the plastered surface, and sometimes the whole is plastered over framework and all. This latter method is employed in larger buildings, and in the "Kuras" or Godouns. A Kura is often many months in building, the mud, which is taken from the bed of some river, being spread over the framework in a great number of layers, each layer being allowed a long time to harden. The projecting timbers at the eaves are also thickly coated with the same clayey mud, and to the small window openings are hinged shutters coated to a very great thickness with the same material. The whole surface of the building is then plastered over, and finally covered with a coating of lacquer. These Kuras often remain standing after street fires, but they are by no means thoroughly fireproof, for the mud often cracks and falls off with great heat, and even under ordinary circumstances they require constant renovation and repair.

In the ordinary houses one external wall or more, and most of the internal walls, are not filled in with plaster, but are open between the uprights, being filled in merely with light wooden screens sliding past one another in grooves formed in the heads and sills of the framework, so that the whole partition can be thrown open at any part. Where light is required these screens are formed of thin wooden framework, divided into rectangles of some simple design, and filled in with tough translucent paper, or in some cases in interiors they are covered with paper, decorated with patterns or paintings. Each room opens into the neighboring rooms, and passages are seldom to be found, except in the largest of houses. Sometimes, however, the greater portion of a room will be raised about twelve inches above the level of the entrance, leaving an L-shaped space or passage on two sides. The raised portion is covered with mats, and used by the indwellers as the room proper. In small rooms the whole floor is on one level, and covered with mats. These mats are always manufactured of one dimension (namely, two feet eleven

inches by five feet ten inches, being twice as long as their width), and a room is invariably built, measured, and described, not according to its actual dimensions, but by its number of mats. They are made of rushes neatly woven upon a light wooden frame, are about an inch and a half thick, soft, slightly yielding and warm. The houses of the highest and the lowest, as well as all temples, have their floors covered with these mats, a little differing in quality. There is generally in one wall of a room a small recess formed in the framework, in which are placed one or two rows of shelves moulded, polished, and lacquered. These shelves are generally arranged in some quaint unsymmetrical manner, and both form an ornament to the rooms themselves, and serve for the display of vases or small ornaments. Even the lowest classes of the Japanese show great taste in judiciously disposing small treasures of good shape and color to the adornment of their dwellings. They convert the smallest strip of land into a miniature garden, which they plant with well-trained shrubs and flowers.

The simple habits of the Japanese, both as regards resting and feeding, renders but little furniture necessary for the complete comfort of the householder. Small low tables, more like what we call trays, are used for serving up food upon—one being set before each guest. A metal-lined box, or sometimes an ornamental bronze receptacle, is used for the small charcoal fire, from which warmth is obtained in cold weather. A room is invariably provided with one or more folding screens which, as the inmates sit or recline on the mats, do not require to be of any great height in order to secure privacy, and keep off draughts in cold weather. Small chests of drawers are to be found in private rooms for clothes, &c., and these, as well as the hibachis, tables and screens are mostly of some elegant shape and pleasing design. If a house be of two stories, the upper story is reached by wooden steps, leading up from room to room, being composed of two strings with treads and no risers, somewhat inconvenient in their slope and generally without handrails. The ceilings of the rooms are wooden, consisting of the underside of the floor boards of the room above, crossed by the small

joists supporting them, and sometimes smaller ribs between, dividing the surface into squares; the whole is polished or lacquered. Probably, in early times, houses of this class were covered with thatched roofs, projecting considerably at the eaves, or were covered with boarding and wood shingle.

In country parts there are now many roofs covered in such ways, but most of the houses in the cities have heavy tile roofs of great projection, with large ridge and hip tiles and terra cotta ornaments at the extremities. The roofs are often slightly concave on their surface, resembling those found on a larger scale in the temples, from which they are undoubtedly copied.

The Shintoo Temples, which are built in imitation of the earlier temples of that region, prior to the introduction of Buddhism, have roofs of two plane sloping surfaces, very salient at the ends and at the eaves; and it seems from this that the heavy curved and hipped roof, which now abounds so in Japan, was an introduction from Corea or China contemporary with the religion of Buddha. The tiles are always of a grayish black color, and the joints are covered with a thick roll of white cement. One great peculiarity is the size of the ridge and hip ornaments, which are constructed of several courses of tiles and cement, forming quite a little wall along the ridge and hips, terminated by large terra cotta ornaments at the extremities. These ornaments are most of them very artistic in shape.

In houses of two stories the upper story is sometimes set back a little, the projecting portion below being covered by a small lean-to-roof. There is often below this another flat roof projecting some three feet from the lower wall to keep off sun and to protect the frail wooden entrances from wet. The roof is generally in part suspended from the roof above, and partly supported at wide intervals by light bamboo posts. Small gutters of bamboo are generally fixed to these lower eaves, with pipes of bamboo to carry off the water. In the hot season "sudaris" (a kind of cane blind which admits air and permits outlook, and at the same time gives shadow from the sun) are hung from the eaves to the ground. The above description applies

both to the dwellings of the lower and the middle classes, the latter being somewhat larger, more cleanly, and better furnished.

The tea houses or hotels are on a much larger scale, and vary in their arrangements. They are very often planned on three sides of a little entrance court laid out as a garden—a verandah with a floor some twelve inches from the ground running round these sides and serving as a passage from one room to another. The upper story also has generally a verandah covered with a salient roof, under the eaves of which paper lanterns are hung at night. In large hotels (called *Yadoyas*) there is generally a small interior court, in one corner of which cooking is conducted in the open air, the rest being laid out in some ornamental manner, with ponds, streams, shrubs, and stone lanterns. Round this is an interior verandah, and often miniature wooden bridges enabling one to cross the court without dirtying the feet.

The dwellings of the higher classes, which are called "*Yashiki*," or "*Miya*," are considerably larger and more architectural. Their arrangement is very simple, being a group of somewhat low rooms, opening one into the other, having a lobby or hall at the entrance, and sometimes one passage from front to back. They are not more than two stories in height, and are covered with a heavy tile roof of wide span with terra cotta ridge and hip ornaments, prominent eaves often supported by a rich cornice of beams and brackets, and having elaborate carving displayed in the gable ends. Over the entrance to the house there is a wide portico, supported upon strong posts which are often moulded on the edges. The lintels, beams and projecting rafters are also moulded on the edge, and carved with some flowing line of ornament, deeply incised upon the flat surface. Such ornament is very effective, being delicately and sharply cut, and can be seen from a great distance. The portico roof is either a continuation of the curved line of the large roof or consists of a smaller roof intersecting this. In the latter case a favorite form is that of a double ogee, convex at the ridge and concave at the eaves, forming a gable or

semi-gable at the front. By this is meant, that on the front the curve of the roof is continued half-way, and is then, as it were, cut off, showing the sides of the end rafters projecting, decorated with bronze clasps and adorned with carved and pierced wooden pendants. In the large roofs the semi-gable is also a favorite form for the ends; in this case the upper portion is of the gable form and the lower portion a sloping hipped-roof. What I have called bronze clasps or belts correspond to what, if placed at the end of a beam, would be called shoes, being gilt and engraved plates of metal placed in the center of exposed beams and lintels, serving for no purpose but ornament. They are much used in Japanese architecture. The windows are generally greater in length than in height, being low oblong openings filled in on the outside with thick wooden bars, arranged sometimes vertically and sometimes horizontally, the whole being open to the air. On the inside of these windows there are always sliding shutters or paper windows, to keep out wet or cold in bad weather.

The Japanese seem greatly to seek privacy for their houses; even when they are placed in country districts they are mostly fenced in. They sometimes have an open loggia to the upper floor as in the hotels, from which they can enjoy the surrounding view; but the approach to the house is invariably shut in, and the lower story hidden by high railings of bamboo. In houses of one story this fence often reaches as high as the eaves of the roof. The Yashikis are shut in in a similar manner, perhaps with a view to protection from treachery as well as the love of privacy. Not only are the whole grounds surrounded by a high wall on three sides, with a long range of buildings and strong gateway on the entrance side, but there is often a high wall or fence close up to the front of the house, through which the open portico projects. Between this and the outer gateway, with its range of buildings, there is a paved court, on the two sides of which servants' quarters, stables, and other outbuildings are erected. From the street the outer gate and its surrounding buildings present in many cases a very pleasing façade. The long horizontal lines of ridge and eaves, as

well as the horizontal effect obtained by the lower story being constructed differently from the upper, is relieved by the vertical window bars and projecting bay windows on each side of the large recessed wooden gateway. The gateway itself is of very solid and strong appearance; thick posts, carrying heavy wooden lintels, which support the upper story over the gateway, from the framework of the heavy doors. Both the posts, lintels, and doors are lavishly shod, belted, and adorned with plates of engraved and gilt bronze. There is in some of these low buildings, marking the approach to a Daimoi's dwelling, a simple grandeur of line of proportion and balance of parts, reminding one as much of the repose and beauty of Greek architecture as the Japanese decorative ornament in many of its forms and in the beauty of its execution reminds one of Grecian art. The walls are generally placed upon a base formed of two or three courses of stone. The lower story, instead of being plastered upon the outside, is sometimes covered with large tiles placed square or diagonally. They do not overlap, but are fixed to the laths, side by side, the joints being protected by a large roll of cement. The tiles being dark grey and the cement white, this treatment presents a somewhat curious, bold, chequered appearance. Placed symmetrically on either side of the gate are often two square projections, about nine feet by six feet, of one story, with an ornamental curved roof and carved gable. They correspond to our bay windows, and command a side view of the gate for porters or a guard who occupies these rooms. These projections have also a stone base, and are framed about four feet from the ground, with window bars and transoms placed very close together. They are protected when necessary by sliding shutters from within. Such windows also sometimes occur at the ends or the center of the range of buildings on either side of the gateway. The other windows are either oblong openings, with thick wooden bars, or they are small projecting windows, framed out some few feet above the ground, and supported on carved or moulded wooden brackets at each end. This framework is sometimes perfectly open at the bot-

tom, the whole front and sides being filled with close bars, and the top covered by a small curved lean-to roof. The inside is protected by sliding shutters flush with the inside of the wall of the room. In some Yashikis in Yedo these projecting window openings are continuous, running nearly the whole length of the building, with brackets at intervals. The whole of the exposed woodwork (gate-posts, lintels and windows) is often lacquered in black or a dull red color.

The smaller and inferior Yashikis are often of one story only, and instead of being plastered or tiled, are frequently boarded with planks nailed on to the wooden framework slightly overlapping at the lower edge to carry off wet. The whole is stained a dull black color. The outer walls, referred to as being placed round dwellings of this class, are either fences made of strong wooden posts and beams covered with planking, and protected with a little tile roof supported upon brackets at the top; or they are of considerable thickness constructed in alternate layers of tiles and cement, the cement being as thick in its layers as the tiles. The top is protected from wet and decay by a little projecting tile roof, with ridge tiles and ornaments similar to the roofs of small buildings. There are no instances of the walls of dwellings themselves being constructed in this way with tiles and cement. At the back of the dwelling within the surrounding walls are large grounds, generally laid out very prettily as a landscape garden. These Japanese gardens abound in grassy mounds and terraces, planted with an endless variety of trees and shrubs fantastically trained, with groups of large stone slabs and boulders, running streams, small lakes, fancy bridges and stone lanterns.

The military architecture of Japan seems not to have been much more substantial than the rest, though many cities contain large moats and the stone walls within which the castle buildings stood. The central portion of the city of Tokio is surrounded several times spirally by a deeply-cut moat with large grassy slopes. Towards the center, this spiral forms a complete enclosure, and on the inside of this inner moat is a thick stone wall constructed in large polygonal blocks, which originally carried wooden defensive con-

structions surrounding the castle within. The larger number of these wooden constructions were pulled down some years ago, but those few that remain form, with the solid walls, deep moats and strong gateways, an extremely picturesque feature of the city. Comparing these remains with a rough plan of a castle, taken from a Japanese book, it appears that there were in the center enclosure of these fortresses three principal buildings of a tower-like form. The most important and the highest of the three, called Homaru, was immediately under the chief in command, and for the use of him and his retainers. The second, which was somewhat lower, called Ninomaru, was devoted to the use of the second in command; and the third, lower still, to the third in command. This last was called "Sannonaru." These buildings were of two, three, or four stories, placed upon a solid battering stone basement similar in construction to the surrounding walls. Each story is set a little back within the lower, the projecting portion below being covered with a very salient roof, adorned in some instances by little excrescent roofs presenting richly-carved gables. The top roof, which is generally hipped, is slightly concave and has a very bold projection. The towers are often oblong in plan, and then the ridge of the roofs ends in a small gable terminating in a hipped roof. These crowning roofs also carry little dormer gables, apparently neither used for light nor ventilation, but as ornament; they are generally little roofs of a curved form. In addition to these dormers the ridge and hip tiles are richly adorned with finials at the extremities, the ridge often terminating in a large representation of a dragon or fish with the tail curled upwards, executed in copper. The walls are thicker than those of ordinary houses, but are constructed of wood filled in with mud and plastered over, showing only the wooden window-frames, which are filled in with thick wooden bars set closely together.

Close to these three central towers is a cemetery for the dead with a little temple enclosed. There are also within the castle wall six or more large Yashikis, being the dwellings of the chief Samurai, or officers of importance, and their retainers. In addition, a large mound

commanding an outlook and several small Shintoo Temples, the principal one being dedicated to Haceman, the god of war. The outside wall, constructed in large polygonal blocks of stone and backed with earth, is interrupted at intervals by large gateway constructions. The ponderous wooden gates are hung to heavy square posts with thick lintels above. These gate posts, some eighteen inches square, often in pairs, are shoed and belted with bronze plates, mostly gilt and engraved. The gates too are generally adorned with metal fittings. The approach is by a permanent wooden bridge erected over the moat. Upon the surrounding wall, built out for the purpose so as to flank those who enter the gateways, are erected towers similar to the interior keeps, though somewhat smaller; and also at all angles of the wall are two-storied towers. Between these buildings and the gateways a low building or shed covers the whole top of the wall, taking the place of the hoarding to our mediæval battlements.

The temples of Japan are by far the most interesting and instructive buildings to be found in the country; set in the solemn shady quiet of their thick groves, approached by their avenues of lamps both stone and bronze; with the grand sweeping lines of the roofs projecting boldly forward, upheld by a profusion of brackets; wooden carving tastefully disposed, sharply and beautifully cut, and the whole woodwork often decorated in well harmonized colors with gilding and bronze ornaments. The principal temples are to be found in Nikko, Osaka, Kyoto, and Tokio (or Yedo). The two principal groups of temples in Yedo are at Uyeno and at Shiba, and at both these places the large central temple has been destroyed by fire. The subsidiary temples, however, are so numerous and imposing, that these sites still rank first in importance in the city as temple groups.

The temples at Shiba are enclosed on three sides by a long wall with several gateways at intervals, and backed by a thick wood of fine old trees. The streets surrounding the walled sides consist of a continuous avenue of pine trees, interrupted only by one large and two small gateways forming the approach to the sacred grounds. The principal entrance

is a large and imposing wooden structure some seventy feet wide and of about the same height. It is built upon heavy wooden pillars arranged so as to form one principal opening and two side ones; these wooden posts being tied together by horizontal beams tenoned to the posts, the sides of the entrances being filled in between this framework with panels of wood. Halfway up, above the soffit of the entrance, which is formed of heavy beams, a tiled roof slightly concave projects forward, and exhibits the ends and underside of numbers of rafters supported upon corbelled brackets. Above this roof the upper story is set a little back and surrounded by an open balustrade; this upper story is constructed of wide posts and horizontal beams with wooden filling in, crowned with a cornice of wooden corbels assisting to support the double rafters of the roof. This roof has the heavy appearance, the concave contour, and the semi-gabled form at the ends which is peculiar to all Buddhist temples in the country. After looking at other religious buildings where every part is painted, carved, or gilt, this gateway might be considered somewhat plain, as it has no carving, and is colored with one uniform dull red color; but it has more claim to grandeur of proportion and general effect than any other building which I have yet seen in Japan; its great size, good proportion, picturesque roof with ornamental crestings, also the numberless corbels, brackets, and rafters, some moulded at the ends so as to suggest the frowning face of a monster; also the deep red color, bright where the sun strikes it, and subdued in parts by the tree shadows and the sharp deep shadows of its cornices and roofs, all these help to fill the beholder with the liveliest feelings of satisfaction. Passing through this portal we find ourselves in a large open space some 200 feet square, in the center of which the large temple stood, now burnt to the ground. Across this space, nearly opposite to the great gateway, is a little temple approached by steps leading to a paved ante-court containing a few tombs and an image of Daibutz in bronze. This ante-court is defended towards the entrance by a screen and low gateway. The most noteworthy buildings, however, are on the right hand side of the open space just

referred to. These buildings consist of the shrines of the 2d, 6th, 12th, and 14th Shoguns and those of their wives, with the religious buildings attached. They were originally approached by two other gates, at some distance to the side of the great gateway which belongs to the large temple now destroyed, but these small gateways are now closed. They are very similar, and it will be sufficient to describe one. The entrance forms the center of three compartments divided by wooden pillars and connecting beams; the two side compartments form recesses for large wooden figures considerably larger than life, and indicative of exaggerated muscular strength and extreme hideousness. The face of one is painted bright red, and the other a livid green; the posts, wooden panels and gates are carved and colored in red, black, and gold, with diapers in color in some parts. The name given to the gate is Nio Mon (Mon-gate), Nio being the name of the hideous janitor who is supposed to guard the entrance to Buddhist sanctities, and whose representation is placed in carving on each side of these gateways. Within the Nio Mon an open space or court is passed, containing several rows of stone lamps, being large stone lanterns placed upon circular pillars with heavy bases moulded and carved, in all about five or six feet high. These were gifts from the smaller Daimios, being offerings to the Shoguns' shrines. Before some shrines there are long avenues of them, increasing in importance as they approach the temple. This court is enclosed by an ornamental screen fence, in which another richly decorated gateway, with heavy folding doors, leads to another court surrounded on three sides by a wooden screen wall carved and painted and protected by a tile roof.

Here are situated the large and elegant bronze lamps which were the dedication offerings of the great Daimios; and, placed in the same court to right and left, are two structures which are found in some form or other before all Buddhist temples of importance. The first or right-hand building consists of a large battering basement slightly concave and built in this case of stone in large courses, upon which is erected a wooden room of one story with a large roof, richly carved and colored roof rafters, brackets, posts,

and panels; also an elegant balustrade carried upon projecting corbelled brackets. The ends of the rafters and the corbels of the wooden cornice are carved in the form of dragons and various beasts; and from the corners of the roof little bronze bells and pendant ornaments are suspended by chains. This is called the bell tower, and contains a large bronze bell which was struck formerly in time of war. At the bottom of this battering stone base is one of the few examples of stone carving actually forming part of a building that I have seen, consisting of panels carved with conventional flowers and foliage.

Facing this belfry, upon the opposite side of the court, is a large granite basin, about three feet six inches by eight feet, diminishing towards the base, where it is ornamented by means of a trefoil cusp form, cut out of the center of each side. It has also on one side two exquisitely cast bronze dragons of small size fixed into the stone, and serving as water-spouts. This basin is covered by a highly ornamental shed, consisting of a picturesque tile roof with gilt enrichments, supported upon angle posts sloping inwards towards the top, where they are tied by cross beams supporting brackets and carving just below the eaves. This shed is a beautiful example of Japanese decorative art. The posts are slightly moulded on the edges, and chiselled on the surface in a simple diaper of lines, the whole colored red. The cross beams which tenon into the posts apparently interpenetrate, their ends reappearing in a moulded form on the other side. They are decorated with a diaper of geometrical design composed of light colors, as are also the groups of brackets above, with the addition of much red and gold. The oversailing rafters of the roof are also richly colored in a similar way, and shoed at the ends with bronze gilt and engraved. The ceiling within is divided by ribs into square panels carved with flowers in relief, and colored with great delicacy and careful imitation of nature. At the further end of this court, where the largest and most ornate bronze lamps are placed, is a long roofed wooden building upon a stone basement, with a gateway in the center. This is the entrance of the cloister preceding the Haiden, as the temple we are approach-

ing is called. The long building is quite open on the inside, being a wooden cloister, or gallery, running parallel to the Haiden, from the center of which another cloister, open on both sides, runs at right angles to the entrance of the Temple. Towards the outside court this cloister presents a range of posts, connected by horizontal beams, filled in with wooden mouldings and carved panels. Above is a wooden cornice, with brackets and projecting roof. The whole being raised above the preceding court presents a stone basement some three feet high, in the center of which are steps leading to the entrance. The gateway is lower than the roofed cloister, but very imposing. The gate itself is placed between large posts flush with the side walls, but other posts are built out and connected with horizontal beams, so as to form the sides of a porch and support the overhanging roof. These sides are filled in, some distance from the ground, with thick panels of wood carved in the form of a writhing dragon of wonderful execution, cut right through so as to be viewed from either side. The wooden posts or columns of this porch are curved inwards towards the bottom and shod with engraved bronze, placed upon a flat moulded stone base, somewhat similar to that of an Egyptian column. They are reeded, and curve in slightly towards the top, where they are also fitted with an ornamental metal socket. These pillars are connected by horizontal beams, apparently interpenetrating their surface, their moulded ends reappearing. The whole is crowned by the ordinary rich bracketed cornice and forest of rafters, and the ornamental tile roof in this case of double curve.

The gateway and whole range of buildings are beautifully colored, consisting of bands and small masses of light color and gilding upon a deep red ground. The posts, beams, and plain woodwork between the panels are red, with gilt bronze shoes, sockets, and belts. A little black is introduced in the form of framework within the main framework of the posts and beams, giving a sort of border to the red panels. In the center of the spaces thus formed is the raised moulded border, of curvilinear form, containing a panel of carving colored in whites, light blues, greens, purples, and

other cool delicate tints. The beams and brackets of the cornice, and the under sides of the rafters, are decorated in light colored diapers, not unlike the mediæval European diapers found in roofs, ceilings, &c. Gilding is lavishly employed, blended with the colors in the diapers, and ornamenting the edges and mouldings of the beams and panels. On the inside, toward the Temple, the open cloisters are composed of richly carved, colored, and gilt posts and beams, with cornice and heavy roof. The center cloister leading up to the steps of the Haiden increases in height, its roof sloping upwards when the steps are reached until it intersects the principal roof.

The whole interior is low, but this is not always the case in Japanese temples, there being many instances of great interior height, though the entrances are indeed generally low. The floor is the only part which is not ornamented in some way, being covered with the ordinary rush mats; in this case, however, slightly wider than those used in houses. The steps between the rooms are of polished or sometimes of lacquered wood. The entrance is closed with heavy double doors, carved and gilt. The interior walls, where not interrupted by sliding doors and windows at the sides, exhibit the same framework of posts and beams, filled in with panels, and crowned with a cornice supporting the ceiling. The first rows of panels—those next the floor—are filled in with paintings upon a gold ground, representing in some cases large growing flowers and plants, and in other cases hideous imaginary animals. Above these the panels are carved in imitation of flowers and birds, such flowers as the lotus and botan (peony) being great favorites; the whole beautifully colored. The posts, slightly projecting beyond the panels, support corbels of wooden brackets forming a cornice, with intermediate brackets and paintings between. The framework is colored red and black, with many metal fittings.

The windows, which admit some light within, are small openings of many-curved outline, filled in with an open arabesque of wood or metal gilt, placed towards the outside, there being sliding shutters or paper windows on the inside to cover them, if needs be. The ceiling

is divided into small squares by ribs, lacquered black, with bronze sockets at the joints: these squares are painted and gilt in representation of dragons. All the painting is done with the most exquisite care and skill. On the outside there are carved panels of birds, plants, and flowers ranged in a line under the colored bracket, cornice, and rafters. The outside is colored red, relieved by the gold, bronze, and the light colors of the diapers and carving.

The roof is a fine example of the ordinary temple roof. It is composed of tiles, covered with thin plates of bronze, which have now assumed a dull gray of a slightly greenish tint. The tiles are alternately flat and semi-cylindrical, and the rolls thus formed along the roof are very effective, added to an ornamental ridge, and richly modeled and gilt terminals. The projecting edges of the tiles at the eaves are gilt, and the cylindrical tiles stamped with the Shogun's crest. The semi-gables which occur at the ends are filled in with carving and pierced wooden pendants, all colored in red or black, as the parts of the building. This Haiden is said to have been completed as recently as twenty years ago—about ten years before the revolution and the overthrow of feudalism in the country.

In addition to this Haiden, dedicated to the three Shoguns interred in the vicinity, we find, further situated to the right, three small Haidens, scarcely less elaborate, dedicated to each Shogun individually, erected at his death, and placed in front of the court preceding his tomb. These three courts behind the smaller Haidens are backed by a high retaining wall, faced with masonry set back, above which are the shrines. They are reached severally by a large flight of stone steps, projecting into the court below. The first reached is the shrine of the 6th Shogun, erected 170 years ago. It is entirely of bronze, and is by far the most handsome of the three. It is some ten feet high, composed of a circular drum with an enriched base upon a stone basement. It is rounded towards the top, and covered with a curved projecting roof formed of bronze, with little chains and bells attached at the corners. Upon the drum is the name of the Shogun sharply cast in the metal, as are

also delicate mouldings and foliage, executed with great sharpness.

The whole is enclosed by a low, thick, bronze railing, with little bronze gates diapered on the surface with the favorite key pattern. The tomb is set back; and, in a line with the front of the wall, at the top of the steps, is a little gateway, with roof and double gates, all of bronze. The heavy gates are diapered with very shallow but sharp ornament; and the side wings, or walls, also of bronze, are ornamented with casts of two peacocks in low sharp relief. All the ornament is much more severe, more sparingly used, and the parts much heavier in proportion than the other tombs and their gateways, which are of stone and wood, and of later date.

At Uyeno, in the north of the city, there are the Haidens and shrines of the 4th, 5th, 8th, 10th, 11th, and 13th Shoguns, being grouped in threes, having one Haiden to each three, viz., the 8th, 5th, and 13th, and the 4th, 10th, and 11th. The arrangement is exactly similar to that of Shiba, but the stone and bronze lanterns are more numerous; the forms of the roofs, and details of carving, and mode of coloring are rather different. Black is much used in the decoration of these buildings at Uyeno. The outer gates are entirely black, with gilt and bronze ornaments, having the peculiarity of a roof covered with small wood shingle instead of tiles. Black is also much used in the decoration of the Haidens, which are otherwise richly colored, as at Shiba. The shrines of the 4th and 5th Shoguns are of bronze, with their railings, gates, and bas reliefs; the bronze has a dull greenish color approaching to black. Though the arrangements and general mode of construction of these sacred buildings are so similar that to describe each involves much repetition, yet there is such a variety of details—such different treatment in points of decoration, both carving and coloring—that there is in them an endless study for the artist.

The carving is generally cut in camphor wood, and the color is mixed with a kind of size which seems effectually to resist the action of the weather. The posts, beams and all large surfaces decorated in one color, are colored with the medium of lacquer; which is either left

of a dead color, or is polished to a great degree of brightness. The bronze shoes and other ornaments are deeply engraved and filled in with black in the hollows.

The Japanese sculptors divide carving into three kinds—shallow, deep, and pierced. In the earlier work, such as the bronze tombs and gates of the earlier Shoguns, the relief is very shallow—at the same time very sharp and effective. In the later work, nearly all carving upon the outside—such as in screens, gateways, and cloisters—is pierced in parts, being cut in a thick slab of wood, and can be viewed from either side. A striking thing in sculpture of this kind is the extremely careful imitation of nature, leaves and flowers being carved with a delicacy and truth to nature that is marvelous, and colored with the same care and beauty. Fruit is gilt, with red dashes of color showing the ripeness: and the greens in coloring the foliage are varied in their tone. Fore-shortening is frequent and well rendered; and though the Japanese artist does not seem to have understood the principles of perspective, which are often violated when dealing with representations of buildings and rectilinear forms, the perspective of all natural forms is carefully noticed and imitated. In Japanese theatre scenery I have also seen interiors of buildings represented correctly in perspective. The third kind of carving—the deep carving—occurs mostly in the interior of buildings when depth of effect is required, but at the same time no communication with the outer air which would be obtained if pierced carving were used. Beams and posts are often diapered with shallow incised carving, the key pattern being a very favorite one, sometimes with the stem and leaves of a plant intertwining. Posts are round, round and reeded, square, or square with the corner slightly rounded or moulded. They are rounded inwards and shod with bronze, both top and bottom, and often a flat bell-shaped capital (similar somewhat to the Egyptian capital called “bell-shaped” by Mr. Fergusson, but flatter still) resting on a stone base of similar form at the bottom. The projections of interpenetrating beams are curled upwards and moulded, or are carved in the form of the fore parts of

lions, elephants, or some animal real or imaginary.

In addition to the shrine temples at Uyeno there is a temple for public worship, called the temple of Gougen, of considerable size, though far inferior to the large temple burnt down during the revolution. It is approached under a Torii along a long paved path, with rude stone lanterns and large trees on either side: this leads to the raised stone platform, or court, which precedes the temple. This is approached by steps and protected by a wooden fence and gateway. This wooden fence is framed with posts and rails, dividing it into three rows of panels horizontally. The centre range is filled in with lattice work of an ornamental character, and the upper and lower ones with carving partly pierced, well-colored, and protected by a little tile roof carried upon a cornice of brackets. The gateway is rather higher than the fence, being covered with an elegant roof of double curve. In this inner court there are elegant bronze lamps; the largest and most ornamental being placed on either side of the steps leading up to the temple door. The temple is nearly square in form, with a small projection at the back containing a sacred shrine. The whole is carved and colored both on the interior and the exterior, the constant use of black and red being noticeable, and carving mostly in light colors.

There are a great many Shintoo temples in the country; the principal one at Yedo being the Kudanzaka. The temple grounds are open, and not surrounded by a grove, as are the principal Buddhist temples; they are entered under a structure found before all Shintoo temples, called a Torii. It is composed of two upright posts of great thickness, generally consisting of the whole trunk of a tree rounded, about 15 feet high, and placed 12 feet apart. Across the top of these a wooden lintel is placed, projecting considerably, and curving upwards at the ends; some few feet below this another horizontal piece is tenoned into the uprights, having a little post in its centre helping to support the upper lintel. These Torii were originally of wood, as is the one at Kudanzaka; but when found before Buddhist temples, which is not unusual, they are mostly of

stone, always showing, however, by their joints and general construction a decidedly wooden origin.

The temple itself is a simple oblong plan, with steps leading up to the entrance, and to an exterior gallery running all round. The roof differs from the roofs of Buddhist temples in being flat and not curved on its sloping surfaces, which are rather steep, and project considerably at the eaves, and in two gable ends. The roof is covered with wood shingle, stained of a dark grey color. At the gable ends there are cross timbers in the shape of the letter X; straddling the roof also at intervals along the heavy ridge, apparently balanced across it are curious beams some 6 feet long, tapering towards the ends. The whole appearance is extremely heavy and curious, and the peculiar forms, such as the cross pieces and beams crossing the ridge, seem to indicate its affinity to the original thatched roof. In some parts of the country the Shintoo temples are still covered with thatch. The construction of the walls of the temple is in the main similar to that of the Buddhist temples, but the wood is uncolored and sparingly decorated with carving. The projecting rafters and ends of beams are generally carved. Color as an exterior ornamentation is by no means found in all temples, even of Buddhist religion.

There is a temple at Asakusa, in Yedo, which is called Honwanji, and which is,

I believe, the largest building in the city; but though remarkable for its great size and height, and for the quantity and exquisite workmanship of its carvings, is entirely devoid of color on the exterior, and the wood has assumed an ashen grey. It is almost square, and is surrounded by a gallery reached by steps, which are roofed over, the posts supporting the roof being shod with bronze, and the beam ends carved into monsters, lions or elephants. The gallery floor is supported upon brackets, which spring from the base of the walls of the temple very near to the ground. Numerous beam ends, rafter ends, brackets, and supports are carved into the most delicate representations of flowers, plants, and birds in sharply cut carving. The roof of the temple rises to a great height. The interior is decorated in color, and, on account of the great span of the roof, there is a peristyle of columns assisting to support it, upon which are groups of corbelled brackets blending with the design of the paneled ceiling. These brackets correspond to similar ones placed round the walls in the cornice over pilasters. The ordinary panels of colored carving are to be seen below.

Yedo and its immediate neighborhood contain some twenty-seven temples of importance, besides many other smaller ones as numerous as London parish churches. To describe properly and fully one temple group would require a Paper to itself.

## SPRINGS.

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### II.

#### SOLID BLOCKS USED AS SPRINGS.

**MATERIAL.**—The springs under this head are made of india rubber, of which immense quantities are imported. From two or three hundred tons in 1830, the importation of caoutchouc into the United States and Great Britain had increased to over one hundred thousand tons in 1870, and to a valuation of many millions of dollars; and the demand is

still increasing, as is the variety of its uses, and the forms of its manufacture.

**THE RUBBER YIELDING TREE** is found in all parts of the world within the limits of the belt formed by the tropic circles—in South America, Mexico, Panama; in equatorial Africa, Madagascar, British India, Burmah, Siam, Borneo and other islands of the Pacific.

The Brazilian caoutchouc (known as

Paran from the port of shipment) is by far the best and most abundant. The tree is of immense size, frequently of over one hundred feet in height and of a girth in proportion. The monarch of the forest where it is found, its lofty and dense crowns are visible for miles away, giving a grandly picturesque character to the naturally beautiful scenery. The tree is tapped after the manner of tapping the sugar maple in this country. The sap is caught in small vessels and, when gathered in sufficient quantities, is dried and stiffened without delay in the smoke of the nut of a species of nut palm\* found in the neighborhood. If not done at once the resin separates from the sap.

The sap gatherer dips his wooden shovel into the white fluid and holds it for a moment in the smoke, or till it becomes of a grayish yellow color and firm and stiff, then he dips it in again, and again holds it over the smoke, and so on till the layers have become six or eight inches thick; the mass is then removed by a knife from the shovel and hung up in the sun to let the water dry out from between the layers.

The color is at first of a steel gray, but soon becomes darker from exposure, and appears as we are accustomed to see it in the crude form known to commerce.

This coagulating process could be much simplified by the use of alum, or the sap could be kept in the fluid state by the use of ammonia, and sent to market in casks (and indeed it is so sent now in some cases), but as long as the gathering of it remains in the hands of the rude natives, the old and tedious process of smoking will without doubt be adhered to; even in this crude fashion a practiced hand can prepare for market five or six pounds per hour. Their unskillful and wasteful methods, however, are fast destroying the trees and annihilating the sources of supply so that serious apprehensions are entertained, and anxious attention is directed to hunting out new sources, and planting and nursing young forests to fill up the gaps created by the wasteful energy of these unskillful and unthinking natives.

\* There are twenty varieties of these beautiful palms in the Amazon Valley. They yield a black fiber called *Pissaba*, which makes excellent cordage. The nuts are excessively hard and beautifully mottled with dark brown.

In the East the process is even more crude than this; the milk is allowed to flow into holes made in the earth at the roots of the trees, and is gathered on earthen moulds into balls and bottles; etc.; the earth being afterwards removed by crushing and softening it in water. The rubber is of lighter color than the American, on account of its being dried in the sun, but contains much more extraneous matter which has to be removed in the subsequent preparation of the material, and is, consequently, of less price in the market.

The older the tree, and the warmer the weather, the richer the juice. More recently there has been found in the East a clinging vine that affords a good yield of caoutchouc: the lettuce, the poppy and some of the *Euphorbia* are said to produce it as well as other plants having a viscid, milky sap.

**PROPERTIES.**—The properties of india rubber are well known; the most useful are its elasticity, softness, and indifference to water and acid, though the latter is not absolute; caustic alkalis have absolutely no effect upon it. It is, however, very sensitive to cold and heat, which destroy its usefulness: at the freezing point of water it becomes rigid and unyielding, and at a high temperature it becomes viscid, offensive and useless: hence the necessity of overcoming these native defects by means of the manipulations which are described below.

It has been observed that when a piece of rubber is suddenly stretched it becomes warm and electrically excited. By digesting it in warm water it may be extended to seven or eight times its original length, without having its contractive powers destroyed. Submitted to severe cold it becomes rigid again and more opaque than when heated. The same results are obtained if the substance remains for a long time in a state of rest, but the original properties are again restored upon the application of a moderate degree of heat.

As stated by Ure and others, the caoutchouc when stretched as above, and suffered to remain in that state for such a length of time as will suffice to destroy its elasticity, increases its density, being under these circumstances 0.9507, whereas, when the elasticity is restored by

heat, the specific gravity decreases to 0.9257.

#### FORMS OF RUBBER SPRINGS.

One of the earliest uses of rubber in springs was made by forming it into a sort of air-tight rectangular, hollow chest, confining the amount of air requisite to fill it, and thus forming a sort of cushion or pillow: when under pressure the air and rubber jointly act as a spring.

AGAIN, A SHEET OF RUBBER was placed between two plates with cogged teeth: under pressure the teeth of the upper plate would tend to press themselves into the spaces between the teeth on the lower plate, the rubber between the teeth thus being subjected to a tensile strain.

A CYLINDER OF RUBBER was circumscribed by a cylindrical piece of metal which was opened by a longitudinal cut, to each of whose sides was attached a straight arm. By this means the rubber could be clamped, it thus acting as a spring to throw open the arms.

A METAL CYLINDER closed at one end and into which another cylinder slid concentrically, and filled with small pieces of rubber; as was also the sliding cylinder, has been made to act as a spring. A ball or sphere can be substituted for the small pieces of rubber.

THE MOST COMMON FORM in which rubber, at present, is used for a spring is cylindrical or barrel-shaped.

RAILWAY BUFFERS are furnished with a series of washers about two inches in thickness, separated from each other by sheet iron plates which allow each washer to be compressed singly, so that every advantage is used and derived from the characteristic properties of the material. To allow the passage of the buffer rod, these washers are pierced in the center with a hole, the diameter of which is larger than that of the plates, so that the depression of the washer may not drive back the rubber against the rod; for the same reason the iron plates are of large dimensions to prevent the rubber from being pressed back beyond the outer edges.

BEHAVIOR OF THE RUBBER.—The laws of the action of rubber under loads have not been sufficiently investigated to give general formulæ for construction in this material.

The form of the cross-section for rubber rings of buffer springs is represented by the accompanying figures.

They have at the upper surface a ring running all around, and at the lower surface a corresponding depression into which the interposing plates fit. For the behavior of such and similar pieces we have the following. The shape of the cross-section of the spring before compression is  $A B C D$ , afterwards it is represented by  $a b c d$ .

The limit of elasticity is reached approximately by a load of  $\frac{1}{2}^k$  per  $\square^{mm}$ , the load being, before compression, on a section normal to the axis. This calculated bearing capacity is somewhat greater (up to  $55^k$ ) for the lighter, and somewhat lower (up to  $45^k$ ), for the heavier kinds of rubber.

The specific gravity of the material varies with the quantity of sulphur incorporated; for the lighter 1, for the heavier 1.15 to 1.32.

The amount of compression within the elastic limit, depends upon the quality of the caoutchouc, and for the metrical system is approximately

$$\lambda = \frac{l}{\gamma} \sqrt{\frac{P}{g}}$$

where  $\lambda$  equals the compression,  $P$  the force,  $g$  the original cross-section in a plane normal to the axis,  $\gamma$  the specific gravity of the material,  $l$  the original thickness of the rubber.

#### EXAMPLE.

A buffer of the form represented in Fig. 7; having an outer diameter of  $74^{mm}$ , a cross-section  $g$  equal to  $11536 \square^{mm}$ ,  $l$  being equal to  $35^{mm}$  and  $\gamma$  amounting to 1; was subjected to a load of  $2500^k$ .

The load then for a unit of surface for the original cross-section is  $P = \frac{2500}{11536} = 0.217^k$ , and according to the formula  $\lambda = 35 \sqrt{0.217} = 35 \times 0.466 = 16.31^{mm}$ . Experiments on the same ring gave  $\lambda = 16.75^{mm}$ .

On railway buffers of this kind from four to seven rings of the above dimensions are used. The total compressibility is evidently obtained by multiplying the compression of each ring by the number of rings.

In the practical use of caoutchouc buffers we often find that they soon lose their elasticity and that ultimately the



## CALENDERING.

The calender now takes the rubber sheets and rolls them to the proper thickness. Machines for this purpose are manufactured at the National Iron Works, (New Brunswick, N. J., Wm. E. Kelley, proprietor). Generally, they are made with three rolls; some are made with four or five rolls, weighing sixty thousand to seventy thousand pounds, the rolls being twenty inches in diameter and sixty-two in length. The distance between them can be regulated to any thickness of rubber. The machines are fitted with spiral connecting gears, preventing back lash and consequently producing sheets without marks or wrinkles.

## CURING OR VULCANIZING.

To make the compound chemically, as well as mechanically, unite with the rubber, *i.e.*, to cure or vulcanize it, it is passed into ovens heated to 250° to 300° Fahr., where it remains from two to four hours, depending upon the thickness and the elasticity desired.

## MAKING THE SPRING.

When the rubber sheet comes from the calender rolls it is wound on a mandrel, the diameter of which fixes the center hole of the spring. To wind it on this iron rod we proceed as follows: first, rubbing on a little soap stone to prevent sticking, a short piece of sheet rubber is taken, of a length sufficient to cover the mandrel, and of a breadth sufficient to envelop the rod. The joint is fastened by a layer of thin rubber the entire length of the sheet, thus forming a tube on the mandrel. The continuous sheet is now wound directly on this tube to the desired thickness. If the spring is to be barrel shaped, it is made so, roughly, by trimming it with a knife to the required shape. Lastly, it is put in an iron mould and placed in the steam heater for vulcanizing. The mould of a six-inch spring is a hollow iron cylinder, whose outside and inside radii differ by one and one-half inches. It is two feet high, has a cap one and one-half inches thick, and has one end closed. The cap is fastened to the top by two bolts, one inch in diameter. To vulcanize a six inch spring it must be subjected to 255° Fahr., for four hours.

## PART SECOND.

## TESTS OF SPRINGS.

In part first were given methods, by means of which springs are tested to determine any want of elasticity, on account of which they would be rejected.

The following is the method pursued in testing a number of springs to determine their laws of resistance, so as to be used for dynamometrical purposes.

The first requisite was a testing machine. The Mechanical Laboratory of the Stevens Institute of Technology contains a machine for testing materials transversely. It is represented in the figure and consists essentially of a mechanism for applying the power or transverse stress, upon a test piece L, and a recording apparatus (not in the figure) by means of which this stress can be accurately determined. The bed-plate of the machine carries a vertical rod to which is clamped a bracket used for the support of a small micrometer screw, having forty threads to the inch, and whose head is graduated into 250 divisions, thus enabling it to measure

$\frac{1}{10,000}$  inches accurately.

To insure accuracy, electric contact is made between the micrometer screw and the test piece: by means of an electric battery of small power, one wire of which is connected with the micrometer screw, and the other to the cross head which abuts against the specimen.

The current also flows through a small electric bell; upon closing contact between the micrometer and cross head the bell rings.

The pressure brought to bear upon the test piece is communicated through the cast iron support D to the bed-plate, and this affects the scale beam, thus indicating the stress applied.

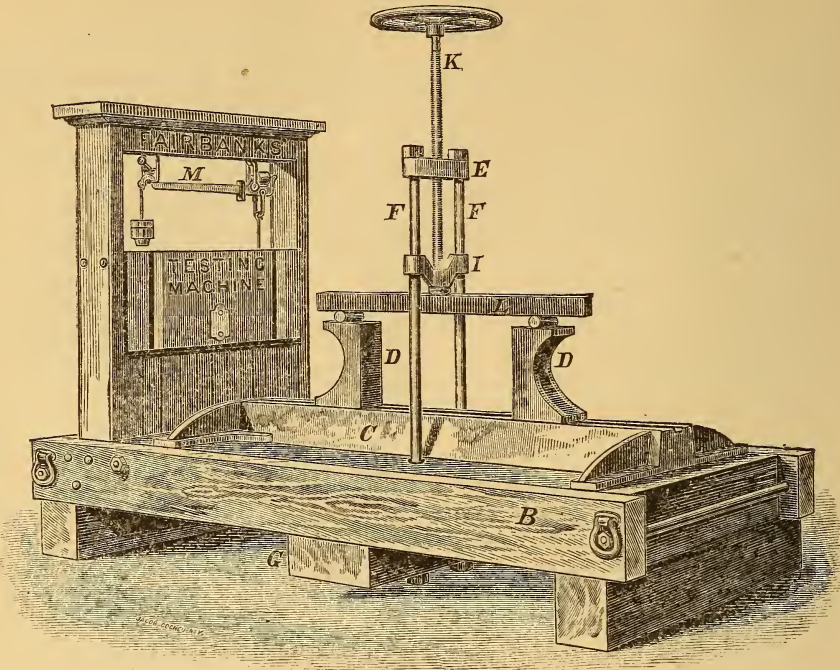
The supports, the tops of which are on the same level, are twelve inches high.

Upon each of these is placed a roller one and five eighths inches in diameter, which are used to ease off the specimen.

The supports themselves rest in a guide groove V cast upon the bed plate; the intermediate distance between them can thus be varied to suit any length of specimen.

The bedplate C is in the form of a cast iron I beam and is firmly secured

FIG. 8.



to the platform of the scale. The square-threaded screw K by means of which the pressure is applied has four threads to the inch and works in a large nut E, supported by two vertical columns, F. These columns are one and eleven-sixteenth inches in diameter and are secured beneath the platform of the scale to a large heavy oak beam G by means of two large washers and nuts.

This beam is forty-six inches in length, eleven and one half inches in breadth, and five and one half deep.

The two columns act as guide rods for the cross head I, with which the end of the screw is provided.

#### TELEMETER.

To test the springs, to determine their laws of resistance it was found that the small micrometer could not be well used as a measuring apparatus; for the cross head of the testing machine, which slides on the columns for guides, could not be made to abut against the top cap of the spring. The cross-head was taken off the machine and the end of the screw was made to abut against the bottom of a cavity made in the top cap of the spring. On the ring of the hand wheel O two grooves were turned, one

on the upper and one on the lower part of the periphery, so as to be able to turn a cylindrical surface on which divisions were graduated. A vertical scale was also added. The apparatus was thus converted into a TELEMETER.

Before using the readings as given by the telemeter, the accuracy of the machine had to be tested; for, under the changed conditions, the deflections were measured by means of the large square-threaded screw before they were measured by the small delicate screw of the micrometer, with electric contact. Errors occasioned by the springing of parts of the machine were taken into account. The testing for accuracy was conducted as follows:

1. By subjecting the apparatus uniformly to an increasing pressure, the rate of increase being one hundred pounds.
2. By increasing the pressure at one-half that rate that is to say fifty pounds.
3. By increasing the pressure variably.
4. By testing without pressure.
5. By taking the screw off the machine and noting its inaccuracies, by placing a scale along side of it.

The first four tests of the machine were made by comparing the readings of the telemeter with those obtained with the small micrometer screw. The method of procedure for the first three was as follows: A bar of wrought iron was placed on the rollers of the transverse machine subjected to a certain pressure, and the deflection as given by the telemeter was noted; a reading was next taken by means of the small micrometer and the difference between the two gave the error. The comparison was made by taking the advance of the cross head for the advance of the screw.

This would be correct if the cross head slid with perfection on the columns; but that is not the case on account of the imperfection of workmanship. If a reading is taken by means of the small micrometer screw, and a second reading is taken, the cross head having been slightly tapped, a difference will be found when reading down to ten thousandths.

Another method that would have given more perfect results would have been to fix the small micrometer screw so that its axis coincided with the axis of the large screw and abutted against its upper head, but this was inconvenient.

The fourth method was to measure the ascent or descent of the cross head by means of the micrometer, and compare it with the ascent or descent as measured by the telemeter.

The fifth method gave results which differed somewhat from the fourth, but the difference is very small: the method of procedure was to count one hundred and twenty threads on the large screw. They should measure thirty inches; for there are four threads to the inch, but observation showed a lack of .04 of an inch; so that the error for one thread is .04

$\frac{.04}{120}$ . The results of the tests by means of the small micrometer are somewhat greater. This increase of error obtained by testing the separate parts or threads may be due to the fact that the threads, from wear, have become thinner without evidently altering the length of the whole screw.

It may be stated that when operating with the testing machine, care should be taken not to subject it to any shock. A

person walking near the machine may produce an error in reading. No pressure should be exerted on the hand wheel and small micrometer: in the former case the equilibrium of the beam of the scale will be disturbed; in the latter, contact will be made before the proper advance of the micrometer screw.

The conclusions of the test are that the main error is due to the springing of parts of the machine, that it is a function of the pressure, the error being .005 of an inch for one hundred pounds; that the errors are very small, and that on the whole the telemeter is accurate enough for practical purposes.

#### FURTHER ARRANGEMENTS.

A casing was necessary in which the spring was placed to keep it in its proper figure—a wrought iron pipe with an outside diameter of three and a half inches and inside diameter of three and one-eighth inches, one end being closed—length of about twenty-three inches. To keep this casing of the spring in its proper position, a wooden support was fitted on the pipe, it fitting also in the column of the transverse machine. A slot was cut into the pipe of about four inches in length and one-eighth inch in breadth, for the purpose of observation while the experiment is going on. The outside and inside surfaces of the closed end of the pipe were made parallel by turning them in the lathe.

#### MANUFACTURE AND DIMENSIONS

The springs were made by Vose, Dinsmore & Co., by heating the steel so that it could be easily wound upon a mandrel, whose diameter equals one and one half inches. They were tempered by plunging them into an oil bath, after coming from the coiling machine, and keeping them there about six seconds, after which they were plunged into a tank of water for about two seconds. The oil bath is kept approximately at its proper temperature by being placed in a tank through which there is a constant flow of water. Before leaving the factory the springs were subjected to the greatest pressure under which they were to be used. The springs are each fitted with two cast iron caps, one is used as a base, and by means of the other, the spring is subjected to pressure. The base cap of the spring was put into a

lathe and its lower surface turned so that the axis of the spring is vertical when supported by the cap. The upper cap is bored out so as to admit the end of the screw of the transverse machine which exerts the pressure. The boring is about one-quarter inch deep and is concave on its base surface. The section of the wire of the coils is a circle, the diameter of which is five-eighths of an inch; the length of the springs originally was eighteen and one-quarter inches, the number of coils of each is nineteen and one-quarter, and each spring weighs twelve pounds.

#### DETERMINATION OF THE LAW OF RESISTANCE.

Spring No. 1 was tested

- 1st, at the common temperature.
- 2d. " " freezing point of water.
- 3d. " " boiling " " "

#### MANNER OF TESTING.

The spring with its casing was placed on the bed-plate between the columns of the machine in line with the axis of the screw; the scale beam was balanced and the hand-wheel turned until the end of the screw just touched the bottom of the cavity made in the top-cap; when the screw through the cap subjects the spring to the slightest pressure it is indicated by the scale-beam; the reading of the telemeter is now taken. The hand-wheel is turned till the scale beam is balanced for an increase of one-hundred pounds pressure and the reading taken; the difference between the two readings gives the deflection for one-hundred pounds which is too great by .005 of an inch, and this amount was subtracted to get the true deflection. The figures in the tables are deflections for increments for two hundred pounds.

At the ordinary temperature the testing was conducted by increasing the pressure uniformly at the rate of one-hundred pounds up to 5,000 pounds at which point the coils were not entirely closed.

The spring was subjected to pressure until the set for five thousand pounds was inappreciable. The set for the test when the table was obtained equals  $\frac{1}{64}$  inch.

The results obtained by the experiments show that the deflection under a

constant, increasing pressure is approximately constant. The valuation, therefore, between the different pressures and deflections will be represented very nearly by the hypotenuse of a right angled triangle of which the altitude equals the total deflection and the base, the total pressure.

SPRING No. 1.

Pressure. Pounds.	Increment of Deflection. Inches.	Total Deflection. Inches.
200	.169	.169
400	.165	.334
600	.163	.297
800	.164	.664
1000	.163	.824
1200	.160	.984
1400	.164	1.148
1600	.163	1.311
1800	.167	1.478
2000	.161	1.639
2200	.163	1.802
2400	.173	1.975
2600	.161	2.136
2800	.171	2.307
3000	.170	2.477
3200	.169	2.646
3400	.164	2.810
3600	.165	2.975
3800	.165	3.140
4000	.162	3.302
4200	.159	3.461
4400	.163	3.624
4600	.151	3.775
4800	.125	3.900
5000	.087	3.987

SPRINGS Nos. 2 AND 3.

Spring No. 2 originally measured  $18\frac{1}{2}$ . It was pressed home, allowed to remain with its coil closed for five hours and then relieved. It had taken a set of  $1\frac{1}{2}$  inches. It was then subjected to a pressure of 5000 pounds for intervals of time, as in the table.

In the 1st it set  $\frac{1}{32}$  of an inch in 18 hours.

"	2d	"	$\frac{1}{16}$	"	14	"
"	3d	"	$\frac{1}{32}$	"	14	"
"	4th	"	$\frac{1}{64}$	"	14	"

Spring No. 3 behaved in the same manner. The table of sets shows that the rate of decrease is one-half when the equal loads act for equal lengths of time.

After the springs were tested for sets, the law of resistance was obtained, as given in the tables. Two tests were made, A and B. A was made first, and

after relieving the spring of all pressure, B was obtained.

SPRING No. 2.

Pressure Pounds.	A.		B.	
	Increment of Deflection. Inches.	Total Deflection. Inches.	Increment of Deflection. Inches.	Total Deflection. Inches.
200	.191	.175	.175	.175
400	.171	.362	.175	.350
600	.175	.537	.171	.521
800	.168	.705	.174	.695
1000	.176	.881	.173	.868
1200	.170	1.051	.170	1.038
1400	.169	1.220	.171	1.209
1600	.168	1.388	.170	1.379
1800	.174	1.562	.168	1.547
2000	.171	1.733	.193	1.740
2200	.172	1.905	.176	1.916
2400	.173	2.078	.174	2.090
2600	.168	2.246	.168	2.258
2800	.183	2.429	.182	2.440
3000	.189	2.618	.171	2.611
3200	.181	2.799	.189	2.800
3400	.196	2.995	.198	2.998
3600	.184	3.179	.180	3.178
3800	.143	3.322	.154	3.332
4000	.085	3.407	.070	3.402
4200	.087	3.444	.065	3.467
4400	.017	3.461	.012	3.479
4600	.022	3.483	.010	3.489
4800	.008	3.491	.007	3.496
5000	.009	3.500	.005	3.501

(Spring No. 3 on following column.)

SPRING No. 4.

Pressure Pounds.	Increment of Deflection.	Total Deflection.
50	.093	.093
100	.094	.187
150	.109	.296
200	.047	.343
250	.094	.437
300	.094	.531
350	.094	.625
400	.062	.687
450	.094	.781
500	.094	.875
550	.093	.963

## VERIFICATION OF RESULTS.

To check the results obtained, as given in the tables, formulæ were used which gave the laws of deflection.

Rankine gives the formulæ  $\frac{W}{v} = \frac{cd^4}{64nr^3}$ ,

SPRING No. 3.

Pressure in Pounds.	A.		B.	
	Increment of Deflection. Inches.	Total Deflection. Inches.	Increment of Deflection. Inches.	Total Deflection. Inches.
200	.185	.185	.185	.185
400	.165	.350	.166	.350
600	.164	.514	.166	.517
800	.167	.614	.164	.681
1000	.164	.845	.164	.845
1200	.164	1.009	.166	1.011
1400	.167	1.176	.164	1.175
1600	.168	1.344	.169	1.344
1800	.166	1.510	.168	1.512
2000	.168	1.678	.163	1.675
2200	.169	1.847	.173	1.848
2400	.177	2.024	.169	2.017
2600	.166	2.190	.166	2.183
2800	.185	2.375	.179	2.362
3000	.181	2.556	.174	2.536
3200	.182	2.738	.172	2.708
3400	.195	2.933	.178	2.886
3600	.188	3.121	.180	3.066
3800	.167	3.288	.165	3.231
4000	.109	3.397	.107	3.338
4200	.062	3.459	.070	3.408
4400	.057	3.516	.053	3.461
4600	.042	3.558	.034	3.495
4800	.021	3.579	.028	3.523
5000	.020	3.599	.019	3.542

SPRING TESTED BY THE MECHANICAL  
LABORATORY

The diameter of the wire equals  $\frac{3}{8}$  of an inch; the length  $3\frac{1}{2}$  inches; the number of coils 14; diameter of spring  $\frac{7}{8}$  of an inch.

where  $r$  equals the radius of the cylinder containing the helical center line of the spring as measured from the axis to the center of the wire,  $n$  the number of coils of which the spring consists,  $d$  the diameter of the wire,  $c$  the coefficient of the rigidity or transverse elasticity of the material,  $w$  any load not exceeding the greatest safe load,  $v$  the corresponding extension or compression; then for springs No. 1, 2 and 3,

$$\frac{100}{v} = \frac{11,000,000 \times \frac{625}{4096}}{64 \times 19 \times 1.19}$$

$$\therefore v = .086;$$

for spring No. 4

$$\frac{50}{v} = \frac{11,000,000 \times \frac{81}{65536}}{64 \times 14 \left(\frac{11}{32}\right)^3}$$

$$v = .11$$

Clark gives  $E = \frac{d^3 \times w}{D^4 \times C}$ ; in which  $E$  equals the compression or extension of one coil in inches;  $d$ , the diameter from center to center of steel bar composing the spring in inches;  $w$ , the weight applied in pounds;  $D$ , the diameter or side of square of the steel bar of which the spring is made in 16th of an inch;  $C$ , a constant which from experiments may be taken as 22 for round steel and 30 for square steel. The deflection for one coil is to be multiplied by the number of free coils, to obtain the total deflection for a given spring. For springs Nos. 1, 2 and 3,

$$E = \frac{10.594 \times 100}{\left(\frac{5}{8} \times 16\right)^4 \times 22} = .0048$$

$$.0048 \times 19 = .0912 \text{ Ans.};$$

for spring No. 4

$$E = \frac{\left(\frac{11}{16}\right)^3 \times 50}{\left(\frac{3}{16} \times 16\right)^4 \times 22} = .00828$$

$$.00828 \times 14 = .12 \text{ Ans.}$$

With reference to the formulæ, we conclude that the one given by Rankine is very approximate. Clark's formulæ gives a result somewhat too large. If the constant is 25 instead of 22, for round steel, it will better agree with the table formed by the experiments.

#### TEMPERATURE TESTS.

To surround the pipe with ice, a casing of wood with a bottom of tin was made, a section of which, perpendicular to its longitudinal axis, is eight inches square. In the pipe, two holes were drilled, one at the upper and one at the lower end. The holes were tapped, and two  $\frac{3}{8}$  inch pipes were screwed into them, the office of which was, to hold two thermometers that noted the temperature of the spring, and were long enough to reach through the ice casing, which had two corresponding holes for the admission of the pipes.

While testing, ice was also let into the main pipe, which extends above the spring, thus surrounding the lower part of the screw of the telemeter, and producing a continuous packing of melting ice upon the spring, besides that which surrounds the pipe.

The test in steam was conducted by generating steam in a small copper

boiler, and conducting it through a rubber tube, to the large pipe, by attaching it to one of the small pipes that are screwed into the casing, the steam escaping through the other small one. The space between the screw of the machine and the pipe casing was stuffed with ordinary waste, to prevent the escape of the steam. Through this stuffing a thermometer was put to note the temperature.

From the results of the investigation nothing definite could be determined, as to any change of the law of resistance, as given by the common temperature tests. The only change found, was in the sets. The spring when in ice and subjected to a pressure of 100 to 5,000 lbs., five times, set  $\frac{3}{16}$ th of an inch. In steam, subjected to the same pressure, the same number of times, it gave a set of  $\frac{1}{16}$ th of an inch.

At a recent meeting of the Royal Society of Edinburgh, Sir W. Thomson gave some explanation of the telephonograph. All previous attempts to record sound were, he said, founded on the motion of a style or marker at a true parallel to the paper. Mr. Eddison's ingenious invention of the electric pen was different. It consisted of a fine point, which, by an excessively rapid vibration perpendicular to the paper, caused by a small electric machine connected with two thin wires to the point, left a trace of any person's handwriting in a row of very fine holes, from which the handwriting could be printed. Mr. Eddison, from this invention, elaborated the phonograph. By the greater or less pressure produced through the action of the alternate condensation and expansion of the air caused by the mechanism of the voice, the diaphragm operated upon the point and recorded the sounds. It was the most interesting mechanical and scientific invention they had heard of in this century. There could be no limit to its application. A man could speak a letter through the phonograph—it would be recorded on tinfoil, sent in an envelope through the post, and his friend, by applying the point of the phonograph to the tinfoil, could reproduce the words and tones uttered.

## MOMENTUM AND VIS VIVA.

By J. J. SKINNER, C. E., PH. D.

Written for VAN NOSTRAND'S MAGAZINE.

IN the May number of this Magazine, Mr. S. Barnett, Jr., begins a review of my articles of November and December, 1877, by saying that the mistakes into which I have fallen arise principally from two causes; the chief one, so far as concerns the reader now, being stated to be a misunderstanding of the question to be solved in establishing an absolute unit of force. A decision as to whether my main opinions are mistakes or not will be made for himself by each reader who has taken the trouble to follow the discussion. It will be permitted to me to examine here whether the articles referred to show the alleged misunderstanding of the question to be solved in establishing an absolute unit of force, and also to consider a few minor points of the criticism.

My reviewer seems to have entirely, and to me unaccountably, mistaken the tenor of my remarks on the "absolute" unit of force. On p. 464 he attributes to me the raising of objections to the "absolute *measure of force*," but I have raised no such objections whatever. On the contrary, I gave at the top of p. 421, Vol. XVII, the rule by which the so-called "absolute" unit of force is defined, viz: "that force which by acting for one unit of time on one unit of mass shall give it one unit of velocity," and stated that there is *no* objection to this method in itself; and on the next page I explained how a balance giving such a unit of force could be graduated in a particular place, if any motives of convenience should make it desirable to use that unit. What I did object to, and what I still think is absurd, is the application of the word *absolute* to the particular unit of force under discussion.

But besides charging me with raising objections to a particular *measure of force*, when I was merely discussing the propriety of a name, Mr. Barnett is apparently talking about one "absolute" unit of force, and I about another. For he would begin (p. 464) by making his units of time and length depend on the time of vibration and length of wave of

a particular kind of light, and then "define the unit of *mass* by its relation to that mass which, by its attraction of gravitation, at unit distance, will produce unit velocity in unit time." Now a unit of mass might theoretically be so defined; but the unit of mass actually taken by those who give the above definition of the "absolute" unit of force, is not determined by any such relation. Thomson and Tait, *Nat. Phil.*, Vol. I, speak as follows on this point:

Art. 221. "It is therefore very much simpler and better to take the imperial pound, or other national or international standard weight, as the unit of mass, and to derive from it, according to Newton's definition above, the unit of force. This is the method which Gauss has adopted in his great improvement of the system of measurement of forces; and by it we have, *and by it only can we have*, an *absolute unit of force*."

Art. 225. "The unit of mass may be the British imperial pound. We accordingly define the British absolute unit force as the force which, acting on one pound of matter for one second, generates a velocity of one foot per second."

Art. 412. "The British unit of mass is the Pound (*defined by standards only*)."

Prof. Clerk Maxwell, *Matter and Motion*, 1876, p. 41, says:

"The unit of mass in this country is defined by the Act of Parliament (18 & 19 Vict. c. 72, July 30, 1855) to be a *piece of platinum* marked 'P.S., 1844, 1 lb.,' deposited in the office of the Exchequer."

My reviewer, p. 464, says that it is hopeless to expect to establish any invariable units dependent upon aggregations of matter. But if the above definitions do not make the ordinarily so-called "absolute" unit of force, depend on a particular aggregation of matter it would be hard to find any unit that is thus dependent. And it is precisely because the British "absolute" unit of force has been made dependent on this arbitrary unit of mass and the equally

arbitrary units of time and length, that I object, not, as Mr. Barnett would have it appear, to the *unit of force*, but to its name.

Whether this name would be any more appropriate for such a unit of force as Mr. Barnett proposes, there will be time to consider when some physicist shall exhibit the unit itself. Mr. Barnett seems astonished that I do not see that by taking one particular definition of the *unit of force*, and calling it an *absolute* unit, we should thereby be put in possession of a wonderful and otherwise impossible means of recovering lost standards of mass and force, in the contingency of a sudden contraction or expansion of the earth and the simultaneous destruction of all platinum units, spring balances, &c. It may be "a mere question of sight." I am inclined to think it is; for I am free to confess that I cannot conceive of any earthly use for such units of mass and force as he proposes, unless there is some means of determining their exact numerical relations to the actual standards used in practical mechanics. But if we have the means now of determining these relations, it follows that we already have the numerical relations of our present standards to the time of vibration and length of wave of each particular kind of light, and therefore that by those relations *it would be just as easy after a grand catastrophe to reconstruct present standards of mass and force without his "absolute" unit as with it.*

It may still be a question with scientists as to what mode of restoring a lost physical standard would insure the greatest accuracy. Mr. Barnett maintains, what is not certain, that if units of time and length were made to depend on the time of vibration and length of wave of a particular kind of light they would thus be absolutely determined for all time. But even if this were granted, the difficulties in the physical construction of a standard unit of mass accurately connected with these units in the manner proposed by Mr. Barnett are by no means slight. If such a standard of mass were once made, and then lost, and if it were required to reproduce an equal mass, having nothing to start from except Mr. Barnett's definitions and his

to consider the probable error of the restored mass, estimating it by what we know of the probable errors hitherto made in experiments like those of Cavendish.

Mr. Barnett's observations on what he seems to regard as a scheme advocated by me for "*deriving* the unit of force," are as wide of the mark as they could well be. For, in the first place, I was not advocating one method rather than another, but simply explaining two possible distinct methods; and, in the second place, Mr. Barnett has wholly missed the point of the explanation. The first method explained was that in which units of time, space and *mass* are arbitrarily taken, and the unit of *force* then defined to be *that force which by acting for one unit of time on one unit of mass shall give it one unit of velocity.* The other method explained was that in which units of time, space and *force* are arbitrarily taken, and the unit of *mass* then connected with them by a proper definition. The arbitrary unit of force generally taken in this method is the weight of a pound. But to make the *pound force* a perfectly definite unit of force we have to specify in what place and at what time the observations for determining it are made, and we must have some means by which those who are to make actual use of the same unit can compare their standards. A practical method would be to say that our arbitrary unit or pound force shall be the force (or pressure) due to the action of gravity on a particular piece of platinum in London at a particular time; and, to have a double check on the accuracy of the observations by which this unit of force is to be registered, we may record its action both in producing the distortion of a properly constructed spring *and in producing motion.* Having then thus adopted an arbitrary and definite unit of force, and provided means of practically comparing other forces with it, a unit of *mass* can be derived from the three arbitrary units by the following definition: *The unit of mass shall be that quantity of matter which, when free to move, and when acted on for one second by a pressure (force) of one pound shall acquire a velocity of one foot per second.* This, briefly, was my explanation of one method of establishing the main units of a

system of mechanics. Let us see what my reviewer makes of this method. He says: "Prof. Skinner, assuming the usual units of time, length and mass, proposes to *derive* the unit of *force* from them." On the contrary, the method was to assume a perfectly arbitrary unit of force, to observe its action and make a record of it by various experiments on a convenient piece of platinum at a particular time, and then to *derive* a unit of *mass* by the dynamical definition just given above. What are the two steps by which this process severs the connection imposed by nature?

Without saying that this system was better than that in which the unit of force is derived by Gauss' definition, I was arguing that writers who prefer to derive the unit of mass by definition from the unit of force ought to first make their arbitrary unit of force invariable, so that there should be a definite ratio between the units of mass and of force in the two systems; and so that students could pass by simple multiplication or division from one to the other. Mr. Barnett says that although the pound is not a weight but a mass, yet the pound weight is a force, and a variable one. Some writers may frame their definitions so as to make their pound weight a variable force, but we have a plenty of others who use the term *pound* consistently as a name of an invariable unit of force. Every writer, for example, who says that a body which weighs 1,000 pounds at the equator will weigh about 1,005 pounds at the pole, assumes in this statement that the pound is an invariable unit of force. It may, and undoubtedly does, lead to more or less confusion, to employ the word pound to mean sometimes a mass and sometimes a unit of force; but since there are hundreds of writers and millions of practical men who use the word in both senses, we have to do the best we can under the circumstances. I accordingly suggested a definition of a *pound force* which should be invariable and should bear a definite ratio to the British "absolute" unit of force, being a quantity of precisely the same kind. Mr. Barnett's talk about my being blinded by the subterfuge of a spring, and of my surrender to Prof. Tait's principle of measuring force, is irrelevant. He writes as if I

had argued against the propriety of ever measuring forces by the motions they can produce. I have done nothing of the kind. I explained that the *pound force*, as determined by the present intensity of gravity at London, was found to be equal to 32.1912 so-called "absolute" units; hence, when I say that forces are properly measurable in pounds I by the same statement make them also measurable in terms of the "absolute" unit. Furthermore, I explained Newton's second law of motion to be actually a rule for measuring the intensities of forces by the *changes of motion* produced by them; although this is not the only legitimate way to measure forces, and no mechanic is ever likely to confine himself to it if another way is more convenient.

Whether a properly constructed spring would not enable us to preserve a more accurate means of practically comparing forces than the resort to experiments on motion may still be a question. The "subterfuge of a spring" has indeed been suggested, even by Thomson and Tait. I quote from their *Nat. Phil.*, Vol. I, art. 406.

"The ultimate standard of accurate chronometry must (if the human race live on the earth for a few million years) be founded on the physical properties of some body of more constant character than the earth; for instance, a carefully arranged *metallic spring*, hermetically sealed in an exhausted glass vessel. The time of vibration of such a spring would be necessarily more constant from day to day than that of the balance-spring of the best possible chronometer, disturbed as this is by the train of mechanism with which it is connected; and it would almost certainly be more constant from age to age than the time of rotation of the earth (cooling and shrinking, as it certainly is, to an extent that must be very considerable in fifty million years)."

Without expressing any opinion as to the merits of this plan I simply observe that if such a spring would answer some millions of years for an accurate chronometer, it would not be beyond all possibility to make a spring that would serve for a short time as a practical means of comparing forces.

Mr. Barnett, referring to my conclusion, drawn from experiments and dis-

cussion, that the word *force* in Newton's second law of motion means no more than *pressure* or *tension*, asks; "How are we benefited by this knowledge?" Simply by realizing clearly what words are properly synonymous with *force*. Mr. Barnett says that by this I mean to prove that *force* is not *the rate of doing work*. To which I reply that the most that a careful reading of my argument on this point develops is that I do not think Prof. Tait's definitions, as given in the report of his Glasgow Lecture, the only necessary and sufficient ones. I did not undertake to show either what *force* or *tension* is or what it is not. I have admitted, Vol. XVII, p. 423, and Vol. XVIII, p. 166, that I do not know in what the intimate nature of *pressure* or *tension* (*force*) consists. I accept it for the present as an ultimate fact of nature. But how does it help the matter to define *force* to be nothing but the name for a *rate of doing work*? If we take this as the only proper and sufficient definition of *force* how are we to define *work*? The general idea of *work* is the *exertion of force* through some definite distance. Thomson and Tait, Nat. Phil. art. 238, say that the *unit of work* is the *unit force* acting through *unit of space*. But if *force* is nothing but a *rate of doing work*, then *work* is nothing but the action of a *rate of doing work*, and we may just as well say that *force* is *force*, and *work* is *work*, and confess that we know nothing of either of them.

The points of Mr. Barnett's criticism remaining to be noticed need not occupy us long. He says incidentally that a penny letter, resting upon a table, has *work* done upon it by gravity. If so, supposing it to remain at rest for half an hour, what is the amount of *work* done, in foot-pounds?

Concerning one of Prof. Tait's expressions in his Glasgow Lecture on *Force*, I had said: "I never saw it stated elsewhere that *the horse-power done by an agent in each second is the product of the force into the average velocity of the agent*, or that *the horse-power in each second* is such a product, or even that *the horse-power* is that product." On which my reviewer says it is to be supposed that I think I see these things stated by Prof. Tait. But that does

not follow. A person familiar with the function of the little word *or* would say at once that all which could properly be supposed is that I think I see at least one of these things stated by Prof. Tait; and whichever thing was stated, it seemed to me could have been much better stated, in an address which was professedly a special plea for scientific accuracy. As Mr. Barnett has kindly pointed out the term which was meant to be synonymous with horse-power, viz., *amount of work done by an agent in each second*, I will simply add that I can find in Prof. Tait's Glasgow Lecture no unit of *work* given except the foot-pound; and that a *horse-power* is not the *number of foot-pounds of work done by an agent in a second*.

Concerning the comparison of *force* and *momentum*, I had agreed fully with Prof. Tait that they are two entirely different things; but, for all that, Mr. Barnett thinks necessary to inform me that a square cannot be affirmed to be a cube. He apparently supposes that my criticism of what seemed to me a poor argument, was given with the intention of discrediting the distinction between *force* and *momentum*. On the contrary I simply suggested that better arguments might have been employed.

Again Mr. Barnett says he is unable to say why I speak of "both" propositions in Prof. Tait's sentence "*momentum is the time integral of force*, because *force* is the rate of change of momentum." I used the word "both" because the sentence contains, for logical purposes, and for the purposes I had in view, two propositions, Mr. Barnett to the contrary notwithstanding. My next words undoubtedly informed most of my readers that I had already presented some objections to the proposition "*force is the rate of change of momentum*;" and I went on at once to state independent objections to the proposition "*momentum is the time integral of force*."

Mr. Barnett says that he cannot imagine what I understand by a *time integral*. He need not try. He may simply observe that although I found that the *integral* of a particular *force*, assumed to increase during five equal increments of time according to a certain law, would be nine pounds, I did not call this or any

other result a *time* integral, as would be supposed from my reviewer's statements.

In another place I had brought together two statements of Prof. Tait's; one being that *force is not an objective reality*, the other that *the product of a force into the displacement of its point of application has an objective existence*. Without admitting or denying either of these statements, I simply suggested the reconciliation of the two as a fit theme for a metaphysician; which suggestion Mr. Barnett seizes as an admission by me that *force* is merely a *rate of change*. To compare two statements made by a

lecturer, is not necessarily to admit or deny the truth of either of them.

Whether or not a writer, with a rational ambition for obtaining the best possible view on questionable points of science, ever allows his zeal to carry him beyond the limits of fair discussion, must of course be left to the decision of impartial readers; but in closing I may be pardoned for saying that I fail to see my reviewer's consistency in beginning such an attack as his with a charge of excess of zeal for controversy on my part, and ending it with a sigh of regret that Prof. Tait's "zeal in slaying" has not yet called forth anything further from him.

## ON THE PROTECTION FROM ATMOSPHERIC ACTION, WHICH IS IMPARTED TO METALS BY A COATING OF CERTAIN OF THEIR OWN OXIDES, RESPECTIVELY.

By JOHN PERCY, M. D., F. R. S.

Journal of the Iron and Steel Institute.

There appeared in the *Times*, of March 6th, 1877, an announcement, in glowing language, of an alleged discovery of Professor Barff, by which iron might be effectually prevented from rusting and, "however much exposed to weather, or corrosive vapors, or liquids," might be rendered "practically indestructible and everlasting." The process consists in exposing iron to the action of superheated steam, whereby it requires a tenaciously adherent coating of one of its own oxides, viz., magnetic oxide, which it is asserted protects the underlying metal not only from atmospheric oxidation, but also from that of corrosive reagents. The fact that magnetic oxide would be formed under those conditions was known to every chemist, notwithstanding the statement of the writer of the article in the *Times*, that it was discovered by Professor Barff. That iron upon the surface of which a coating of magnetic oxide has been formed, by the joint action of heat and atmospheric air, is preserved in a greater or less degree from rusting is a fact well known, I should suppose, to every member of the Institute before the announcement of Professor Barff's discovery; and, per-

haps, the most striking example that can be adduced in proof of such protective action is afforded by a variety of Russian sheet iron. In a pamphlet which I published in 1871, I described the special character of this sheet iron, and communicated such information as I had been able to procure concerning its manufacture. The following is a quotation from that pamphlet:—"A particular kind of sheet iron is manufactured in Russia, which, so far as I know, has not been produced elsewhere. It is remarkable for its smooth, glossy surface, which is dark metallic grey, and not bluish grey, like that of common sheet-iron. On bending it backwards and forward with the fingers, no scale is separated, as is the case with sheet iron manufactured in the ordinary way by rolling; but on folding it closely, as though it were paper, and unfolding it, small scales are detached along the line of the fold . . . . This sheet iron is in considerable demand in Russia for roofing, and in the United States, where it is largely used in the construction of stoves and for encasing locomotive engines."

Now, from the circumstance of its

being applied to the purposes just mentioned, especially roofing in such a climate as that of Russia, it may be inferred that it must be much less liable to rust than ordinary sheet iron; and of the correctness of that inference I have had personal experience. In 1846, I constructed, of this Russian sheet iron, a gas combustion furnace for organic analysis which I exhibited to the meeting of the British Association, at Southampton, in the same year. Ever since that period the furnace has been exposed to the atmosphere, sometimes to that of a laboratory, and yet it presents only here and there small spots of rust. Other specimens of similar sheet iron, which I have had in my possession for fifteen years and upwards, remain free from rust, notwithstanding that they have also been freely exposed to the atmosphere.

The metal used for the sheet iron in question is made from pig iron, either in a charcoal finery, or the puddling furnace; but according to one account, only in the former. The pig iron is produced by smelting magnetite, spathic iron ore, and red and brown hematite, with charcoal and cold blast. For a detailed account of the process of manufacture, I must refer the members of the Institute to the pamphlet which I have mentioned, but there is one operation to which I invite their attention, and which is conducted as follows:—The rolled sheets are sheared to the dimensions of 28 inches by 56 inches: and each sheared sheet is brushed all over with a mixture of birch charcoal powder and water, and then dried. The sheets so coated, with a thin layer of charcoal powder, are arranged in packets containing from 70 to 100 sheets each; and each packet is bound up in waste sheets, of which two are placed at the top and two at the bottom. A single packet at a time is re-heated, with logs of wood 7 feet long placed round it, and, for this purpose, a furnace of particular construction is employed, which will be found fully described and illustrated in the pamphlet referred to, and a copy of which I herewith transmit. It consists of a re-heating chamber above and a fire-place below, the two being separated by a floor, containing holes, through which the gaseous products of combustion from the fire-place pass into the upper chamber. The object, it is

stated, of the logs of wood is to prevent as far as possible, the presence of free oxygen in the re-heating chamber. The packet is thus slowly heated for five or six hours, after which it is withdrawn and hammered. Now, during a considerable portion of this period steam would continue to be evolved from the logs, and it becomes a question, whether that steam may not be instrumental in forming a superficial coating of magnetic oxide of iron on the sheets of the packet. But it was not until I had read the account of Dr. Barff's process that this notion occurred to me. If it should prove to be well founded, then another would be added to the many remarkable instances in metallurgy of practices having been introduced, and long carried on, without even a suspicion of the scientific principles which they involve.

Assuming the correctness of what has been asserted concerning the action of a coating of magnetic oxide of iron in preserving iron from rusting, it seems extremely probable that such action is due in great measure, if not wholly, to a peculiar physical state of the oxide. One condition is also essential, namely, the perfect continuity of the coating; for I have observed that when an article which had been coated by Prof. Barff himself, and from which the oxide had been expressly removed in one or two places, was exposed to the joint action of air and water, especially salt water, rusting speedily took place at the denuded places, and proceeded with rapidity; but whether more rapidly than in the case of ordinary sheet iron, exposed to similar conditions, I cannot state, as no comparative experiments were made. This, however, is a point which will deserve particular attention.

I trust that, in submitting the foregoing remarks to the meeting of the Institute, a desire to disparage Professor Barff's application will not be imputed to me. So far from having any such desire, I have pleasure in expressing my opinion that great credit is due to the Professor, both for the originality of his proposal and for the manner in which he has experimentally investigated the subject.

The next example which I have to submit to the Institute of the protection

from atmospheric action afforded to a metal by a coating of its own oxides is copper, and it is a very striking one. For more than a century, European metallurgists have been familiar with small thin bars of cast copper, of Japanese manufacture, which present a beautiful rose-colored tint, due to an extremely thin and pertinaciously adherent film of red oxide of copper, or cuprous oxide. This tint, according to my experience, is not in the least degree affected by free exposure of the bars to the atmosphere. I have had such bars in my possession for more than thirty years, and, although they have been freely exposed to the atmosphere during the whole of that period, yet they have not undergone the least change in appearance; they remain as bright and as beautifully colored as they were when I received them. Now as every one knows, when a piece of ordinary copper is exposed to the atmosphere it speedily acquires a dark-colored tarnish. Hence the conclusion that there is some peculiarity on the surface of the Japanese copper which protects the underlying metal from atmospheric action; and that peculiarity it may be demonstrated, is the presence of a film of cuprous oxide, in a particular physical state which acts like varnish. The bars of Japanese copper are actually cast under water, the metal and the water, previously heated to a certain degree, being poured at a high temperature. I have fully described the process in a volume which I published in 1861, and I have recently obtained additional information on the subject from my friends, Messrs. Tookey & Godfrey, who have witnessed this singular process of casting in Japan. I have also succeeded in thus casting copper under water. It would be out of place, on the present occasion, to describe the process in detail. All that need be further stated is, that when copper is so cast, under suitable conditions of temperature it acquires a coating of cuprous oxides which acts in the manner described. The temperature is such that the so-called spheroidal action of water comes into play and the metal flows tranquilly under water. The superficial oxidation is probably due to the action of a film of steam which there is reason to believe surrounds the copper under these con-

ditions: and when copper is heated to a high temperature in steam, the latter as shown by Regnault's experiments, is decomposed with the evolution of hydrogen and the formation of cuprous oxide.

The last example of the action in question, which I shall mention, is afforded by lead. In the collection of the Museum of Practical Geology, in London, is a number of very thin sheets of lead, coated with bands of varied and extremely bright colors. Although the atmosphere has had free access to these sheets for about thirty years, the colors are as intense and as bright as they were at first. The sheets were prepared at Mr. Beaumont's smelting-works, by dexterously skimming in the process of desilverizing lead by Pattinson's most original and beautiful process; and were presented to the Museum by Mr. Sopwith, at that time general manager of Mr. Beaumont's mining and smelting establishments. The colors are certainly caused by excessively thin films of oxide lead of various thickness.

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[NOTE.—Colonel W. H. Paine, of the Corps of Engineers of the East River Bridge, produced by a process of his own in 1869 a surface of magnetic oxide upon steel measuring tapes, which has proved a perfect protection from further rusting and the tapes are yet in good condition.—ED.]

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A COMMISSION has, it is stated, been appointed by the Belgian Government, consisting of twenty prominent civil and mining engineers, iron manufacturers, architects, and railroad officers, to enlarge the field for the consumption of iron. The report of the Minister of Public Works, in accordance with which the commission was appointed, urges the investigation particularly as likely to increase the demand for the products of the Belgian ironworks, which have long been suffering for the want of sufficient orders. The Minister mentions that in his department already experiments have been made in renewals of wooden railroad ties by an iron substructure with hopes of success, and he mentions as worthy of attention the substitution of iron for wood for frames, floor beams, cranes, scaffoldings, &c., in building; for supports, &c., in mines, &c.

## MARINE ENGINE FRICTION.

From "The Engineer."

ALTHOUGH Mr. Isherwood, of the United States Navy called attention many years ago to the great loss of power which resulted from the friction of marine engines, it is only recently that much attention has been given to the subject in this country. Plenty of evidence that this loss is very considerable, and that friction entails very objectionable consequences, is however not lacking; and it is possible that marine engine builders may yet see their way to reducing both the loss of power and the trouble caused by friction by an appreciable quantity. So long as the effects of undue friction are rendered manifest only by the heating of bearings which can hardly be kept cool by an affusion of cold water, they are passed over with comparative neglect. It is to be hoped that the labors of such men as Mr. Froude, and the convincing proofs that he can supply that engine friction in all its forms represents a dead loss to the shipowner, may operate more forcibly than the complaints of the unfortunate sea-going engineer, whose whole life in the engine-room is rendered miserable by the fear that they may have a hot bearing at any moment. It has often been asked by those whose experience is confined to stationary engines, why it is that so much trouble is experienced at sea from hot bearings? The fact is that, on land, engines are worked under very different conditions from those which obtain at sea. Very few land engines work up to anything like the power developed by marine engines. If our readers will now draw on their own experience, they will find that the number of stationary engines in factories, ironworks, or mills indicating more than 500-horse power may almost be counted on the fingers. It is found better in such establishments to divide the motive power among several centres of distribution, than to concentrate it all in one place. But it is no exaggeration to say that there are thousands of marine engines indicating more than 500-horse power; and it is well known that small marine engines seldom give much trouble with hot bearings.

The larger the engine, the greater the chance of heating. Mr. Froude has designed an exceedingly ingenious dynamometer for ascertaining the loss of power by engine friction; but apart from this apparatus, he has been able to get at facts of extreme interest bearing on the subject. The method he adopted he described during the discussion which took place on Mr. Holt's paper on "The Progress of Steam Shipping," read before the Institution of Civil Engineers on the 13th of last November. We can best explain the nature of this investigation by quoting Mr. Froude's own words:—"Mr. Denny, of Dumbarton, had not been content with the usual mode of trial of his ships at what is called full speed and half boiler power, or half speed, but he decided that he would get a regular progression from the highest powers he could deliver to the lowest, and correlate them with the speed of the ship. In that way a series of interesting results was obtained, and expressed in the form of a diagram, in which a base line represented units of speed, and a series of vertical ordinates erected on it the horse-powers. A curve uniting the ordinates at the top could now be drawn, and the curve thus drawn went through the zero of horse-power at the zero of speed, in virtue of the speed factor in indicated horse-power. But when the matter was separated into its constituent elements, a totally unexpected, but most instructive result, was obtained. Dividing out from the horse-power the speed factor, propulsive force was obtained, or the equivalent. It was usual to represent the work done by an engine by the product of the pressure on and the speed of the piston; but it might be described equally well—on the supposition that no friction existed—by the product of the virtual speed of the screw and the force delivered by the screw. Now, using the force factors thus deduced from Mr. Denny's experiments as ordinates, at each speed a curve was obtained in which the force ordinate refused to come to zero at the speed zero. The lowest speed was about three or four knots, and a fair

curve drawn through the force ordinates given by the succession of speeds, instead of being a curve running down to zero, was a curve that terminated on an ordinate about one-seventh of the maximum force ordinate delivered at the highest speed. That, when looked into, represented the dead friction of the engine—the force required to turn the engine round when unloaded. A variety of ships was tried in that way, and all the curves, when analyzed, yielded the same result." In other words, we have no less an authority than Mr. Froude showing that one-seventh of the power of a marine engine is wasted in friction. Of course, this does not all concern shaft bearings; but it will be admitted that, concern what it may, it represents a very serious loss. To put it in plain terms, for every 600 tons of coal which a steamship expends in propulsion, she must burn another hundred in simply working her engines; and it becomes evident that the loss thus involved may become a very serious item in the expenses of such steamers as those of a couple of thousand tons cargo capacity running to India *via* the Suez Canal, and propelled by engines indicating from 500 to 700-horse power, to say nothing of fast passenger ships, indicating three or four times as much, and making equally long voyages. Of course it is impossible to get rid of all friction, but it is quite certain that as much can probably be saved by reducing it as by jacketting cylinders, or adopting other means of economising the consumption of steam.

The question is now, can friction be reduced? It is obviously impossible to consider this problem in all its aspects within the space at our disposal. We shall deal, therefore, for the present, with one point only, namely, crank shaft friction. In the course of the discussion, to which we have already referred, Mr. Froude stated that an instance had come under his own observation in which the friction of a crank pin 22in. in diameter and 22in. long, was so great that, assuming the coefficient of friction to be one-fifteenth, "it came out, when the engine was working at its greatest speed, that work delivered on the crank pin in the shape of friction was almost equivalent to a delivery of heat at the rate at which heat is delivered to the internal surface

of the fire-box of a locomotive. The heat delivered at that rate had to be radiated away or got rid of in some manner by the crank arms and connecting rod brasses, but there was a great deal of heating and trouble with the bearing." To make this statement thoroughly intelligible, let us take a somewhat similar case. The low-pressure cylinder of a compound engine is 90in. in diameter; the crank pin is 20in. in diameter and 20in. long in the connecting rod brasses. The boiler pressure is 80 lbs. on the square inch, and the net pressure on the large cylinder at the beginning of the stroke is a little over 30 lbs. absolute. This brings a load of rather over 85 tons on the crank-pin at the beginning of the stroke, or 477 lbs. per square inch of crank-pin bearing surface, assuming that surface to be equal to one-third of the whole surface of the pin. The average pressure throughout the larger portion of the stroke will not be much less than 20 lbs. To be on the safe side, let it be taken as a little over 14 lbs., equivalent to, say, 40 tons. The revolutions per minute are 50, and any point in the circumference of the crank-pin thus passes over a distance of 262ft. per minute. Taking the coefficient of friction at  $\frac{1}{15}$ , we have  $\frac{896,000}{15} \times 262 = 1,565,013$  foot-pounds per minute, or over 47-horse power. But the load and pressure are not confined to a single journal, and, assuming that there are two main bearings for one crank-pin, then each of these will offer a resistance equivalent to one-half that of the crank-pin. The gross frictional resistance of the three bearings will therefore amount in round numbers to 96 indicated horse-power, and all the work thus done takes the form of heat. Now a horse-power of 33,000 lbs. raised a foot high in a minute represents, according to the latest researches, as nearly as may be, 42.63 British thermal units per minute. In order that the crank-pin may be kept cool, over 2000 units of heat must be got rid of per minute. But this heat would suffice to raise 20 gallons of water per minute from 50 deg. to 150 deg. It is not remarkable that, under such conditions, water has to be turned on bearings which cannot dissipate heat by radiation and conduction sufficiently fast. Indeed, the ex-

penditure of heat in this way is a tolerably constant quantity, and there is little reason for doubting that in most marine engines the production of heat by friction, and its expenditure by conduction and radiation, are very nearly balanced. That is to say, there is scarcely any safe margin. The slightest increase in the coefficient of friction by defective lubrication may upset the balance between the influx and discharge of heat, and thus a crank pin which is at one moment running cool may five minutes afterwards be nearly red hot.

A moment's thought will show that the way to avoid hot bearings at sea is to reduce the diameter of the journals concerned, and to augment their length. For example, if the journal which we have selected for an example were 10 inches in diameter and 40 inches long, it would have the same bearing surface as though it were 20 inches by 20 inches, but the distance passed over per minute by the surface of the crank pin would be

reduced one-half, and the heat imparted to it would be reduced in the same proportion. When a fly-wheel bearing heats the engine is run more slowly until it cools down, but reducing the diameter of a bearing has precisely the same effect. Forty inches of length is an impracticable dimension for a crank pin, but the pin might be made 12 inches in diameter and 20 inches long without fear of injury as far as the brasses are concerned, because the effective surface, being 240 inches, the load per square inch would be only about 850 pounds on the square inch, and this only at each end of the stroke. But it is obvious that no such reduction in the diameter of a crank pin is admissible if it has to transmit the driving force of a second cylinder to the screw shaft. The deduction is, that in so far as concerns crank pin friction, single-cylinder engines of the American type must have a great advantage over those with two cylinders.

## ON OBELISKS—THEIR PURPOSE, PROPORTIONS, MATERIAL AND POSITION.\*

From "The Builder."

THE generous patriotism of Mr. Erasmus Wilson, and the skill of Mr. John Dixon, C.E., have triumphed over the half a century of England's indifference, and now the monolith of Alexandria is in the Thames only awaiting, after much discussion and difference of opinion as to its proper site, to be erected in the very centre of our metropolis as an evidence of the grand ideas of the ancient Egyptians in regard to monumental art. Considering how intimately obelisks are connected with our pursuit, I have felt that it would hardly become our Institute if such an historical fact were unnoticed in our annals, and if some attempt, however brief, were not made by us to get together the leading points connected with the general subject of obelisks, their purpose, proportions, material, and position, treated from a strictly architectural point

of view, without encumbering ourselves with the questions relating to precise dates, or intricate calculations of dynasties or to hieroglyphics.

They are the most simple monuments of Egyptian architecture, and among the most interesting that antiquity has transmitted to us, from the remoteness of their origin and the doubt in which we still are as to the period when first set up. The oldest, which now remains to us, is still standing at Heliopolis, near Cairo—the On, Ramses' or Beth-Shemesh of the Hebrew Scriptures. Abraham was unborn, the Pentateuch of Moses was not written, when the inhabitant of Heliopolis adored his gods in the Temple of the Sun, and read upon the obelisk, still in its place, the name of Harmachis and that of King Osirtesen, who then reigned and reared it, and to whom Mariette Bey assigns the date of 2851 years before Christ. He was a powerful

\* From a paper by Professor Donaldson, read before the Royal Institute of British Architects.

Pharaoh, whom eleven royal dynasties had preceded, and who was followed by twelve more, when Alexander the Great, about 380 B.C., came to consult the oracle of Ammon, and to found at Alexandria, the capital of his future Egyptian empire. They are supposed to have been principally dedicated to the sun-god Horus, of whom the hawk was a symbol, on account of the elevation to which this bird extended his flight, and of the faculty, which the ancients considered it to have, of looking at the sun with a steady gaze.

Obelisks have been, from the earliest periods of antiquity, regarded as remarkable monuments of the skill and perseverance of remote ages. They must ever be considered as valuable records of the ancient history of the Egyptians and of the skill of those periods; monumental evidences of their sovereigns and of their warlike exploits. Extracted with vast labor from their quarries as monoliths, conveyed six or seven hundred miles down the Nile, and erected with difficulty in front of their temples, they are emblems of the perseverance and love of glory of the Egyptians or their rulers. Overthrown by earthquakes or the violence of conquerors, buried in the sands, or encumbered by the enormous blocks of stone piled up to great height, the city of Thebes, even in its dilapidated state at the present day, is the marvel of the traveler for the extent and dimensions of its ruins. The ancient city, divided in its middle by the Nile, as London is by the Thames, presents two gigantic towns with remains of immense temples, which in all their accompaniments and parts are colossal, whether in the dromoi or avenues leading up to their entrance portals, their statues, their courts, and colonnades, in the hypostyle halls, and last, though not least, as objects of wonder, in their stupendous obelisks. These were lofty pillars of granite set up by the kings in front of their temples, to commemorate their victories and record their various names and titles. I am not aware that they have as yet been found in front of tombs, as suggested by Mr. Basil Henry Cooper, in his learned paper recently read before the Society of Arts. They were monoliths consisting of a square shaft gradually diminishing towards its

summit up to about nine diameters high, where the faces suddenly receded up to a point, their upper portion being called a pyramidion, from the similarity of its general form to that of a pyramid, though much more rapidly sloping. I have said receding up to a point, but the fact is, that there is authority for assuming that sometimes the pyramidion had a seated figure on its top.

The Egyptians set great value upon the size of their monoliths, and if a large block were extracted from a quarry not quite corresponding in all its sides, whether as to size or form, they would without scruple use it for their immediate purpose, or shape it as near as possible to the object they had in view, without diminishing its size. The consequence is that many of their obelisks, pedestals, and sarcophagi even, where one would have supposed the most scrupulous attention to uniformity should have existed, are irregular in shape. In like manner some of the huge blocks intended for obelisks came out of the quarries mis-shapen at the smaller end, and to remedy this defect they covered it with a metal capping of the required shape rather than reduce its length by cutting off the rugged portion.

The summit of the Parisian obelisk was irregular in shape, and left quite rough. There was at the bottom of the pyramidion a channel and fillet, then a surface setting back, and the granite presenting an uneven face. It was in the same state previously to its being lowered by the French. There must have been something to cover this unsightly appearance. Our obelisk has an inscription, translated by M. Chabas from the transcript of Burton's "*Excerpta Hieroglyphica*," pl. 51. In it is the following line:

"He erected two very great obelisks capped with gold."

Mariette Bey mentions that round the lowest part of the obelisk of Hatasou runs an inscription in horizontal lines covering the whole of its four sides, which states that the summit of the obelisk was covered over with pure gold, taken from the chiefs of the nation; and he observes that, unless this expression simply implies an apex overlaid with a casing of gilded copper, as the top of the obelisk must have been, this inscription possibly refers to the sphere of gold (?)

which is represented on certain bas-reliefs at Sakkarah. He further says: "The obelisk was no doubt gilded from top to bottom." In examining closely, one may notice that the hieroglyphs were carefully polished, and, moreover, that the plain surface of the monument was left comparatively rugged, from which it may be inferred that it had been covered with a coating of white stucco, as so many Egyptian monuments were, which alone received this costly embellishment of gilding, the hieroglyphs themselves retaining the original color and actual surface of granite. Dr. Birch mentions that the tombs in the Libyan range behind Gournah and El-Assasif "are full of scenes of the reign of Thothmes. Two great obelisks of 188 cubits high, with gilded tops, are recorded in these sepulchres." Mariette Bey also says that, "the inscription further states that the two granite obelisks of Heliopolis were actually completed and erected in seven months from the very beginning, when first extracted from the quarry in the mountain." This use of bronze caps seems to justify the practice in modern times, as the ancient Romans possibly adopted in certain cases the same practice; and this has been handed down traditionally to our period.

When the pyramidion was perfect in its shape, and required no artificial capping, it was sculptured in sunk relief, with a representation, as on the Alnwick obelisk, of the god to whom the monument was dedicated, before whom was the king kneeling and presenting his offering, or by a group consisting principally of a sphinx on a pedestal in front of a deity seated on a throne. A very fine example of the apex of an obelisk, at Karnak, is to be seen in the full-sized cast of one side of a pyramidion, on the landing at the top of the staircase leading to the Egyptian Room, in the upper gallery of the British Museum. Imposing from its size and execution, it shows the bold depth of the hieroglyphs and rounded surface of the sunk character, polished, as Mr. Erasmus Wilson suggests, like the delicate carving of a gem.

The next division of our subject relates to the shaft of the obelisk. The sides were not always equal in their width, varying a few inches. In the ex-

ceptional instance of the obelisk of Bigge or Crocodilopolis in the Fayoum, called by Mr. W. R. Cooper, in his able book on this subject, an obeliscoid monolith, the faces are 6 feet 9 inches broad, the sides only 4 feet thick. Our London obelisk is at the base 7 feet 10.3 inches by 7 feet 8 inches; at the summit, 5 feet 1.3 inches by 4 feet 10.25 inches,—an inappreciable difference. The four sides or faces of obelisks were usually square, but occasionally they are convex; a fact proving the nice perception for effect, which prevailed in the minds of the ancient Egyptians, as thus the light was much softer upon the surface, the shade less crude, and the angles less cutting. Whether there is in any an entasis in the upright line has not yet been precisely ascertained, but perhaps this fact may now be set at rest in respect to our Alexandrian obelisk. Usually obelisks had one, two, or three vertical lines of hieroglyphs. Originally it may be assumed that only one central series was contemplated by the original Pharaoh; but it appears that his son, successor, or successors, added a line on each side; and it is remarkable that earlier hieroglyphs were much deeper cut than the more recent ones. Occasionally some of the hieroglyphs have been altered or erased, more or less deeply cut, and the names of other gods or Pharaohs have been substituted, like the inscriptions upon some of the Roman triumphal arches. I just now noticed the mention made by Mariette Bey of the faces of obelisks having been gilt, the hieroglyphs themselves retaining their original color and actual surface of granite. It is not impossible that occasionally the hollows of the hieroglyphs may have been filled in with some colored substance, in like manner as we see on the frescoes the hieroglyphs painted in different colors, like those preserved in the Egyptian Hall of the British Museum. These inscriptions are generally trivial and meaningless, recording little more than the names and patronymics of the king, his relationship to the gods, and list of his virtues, and of the people he may have subdued in battle; sometimes with maxims and blessings of the gods.

We have now to consider the dies, pedestals, and steps upon which the obelisks were anciently raised. On this

subject we have very little reliable information, for the bottom portions of those now left standing in Egypt are encumbered and surrounded by huge fallen blocks of stone, preventing their full size from being ascertained; and on those transported to Constantinople, or Rome, or elsewhere, from their original sites, no reliance can be placed. Our late friend, Mr. Joseph Bonomi, may be considered a great veteran authority on the subject of obelisks, as he made it a special object of study when in Egypt and in Rome; and there is a very complete enumeration and analysis of existing monoliths by him in vol. i. of the Second Series of the Transactions of the Royal Society of Literature, 1843, and a description of the Alnwick Obelisk. By his liberality the Institute possesses two fine models of obelisks at Karnak and Luxor. In a private letter to myself he says that he had seen the upper part of the block of granite on which that of Karnak stands—"It is cubical; on two sides the surface is vertical, on the two other sides the surface inclines very much, but the exact angle I do not know, nor do I know how high the block is, for the lower part is encumbered by large masses of stone." The model was made for the late Duke of Northumberland (Algernon Percy). This divergence of the faces of the die is a remarkable confirmation of my previous remark as to the irregularities existing in large blocks of granite, from the desire of the Egyptians to retain, as far as possible, the cubical mass entire. Mr. Bonomi concludes his note by stating that he had measured and drawn the base of the obelisk at Luxor; that it was composed of several pieces of granite, and on the north and south sides had four statues of monkeys cut out of two or three blocks of granite in *alto relievo*. On the east and west sides are sculptured in Egyptian *cavo relievo* (hieroglyphs) figures of Nilus bringing in the productions of the country. This extraordinary mode of embellishing the pedestals of obelisks seems almost incredible, were it not for this instance, which is illustrated and detailed by M. Le Bas, the engineer, who transported the Luxor obelisk to Paris, where, however, the original pedestal forms no part of the present composition in the Place de la Concorde.

This obelisk, as described by M. Le Bas, deserves our special notice, on account of its individual peculiarities.

Ramses II., whose reign began 1388 B.C., extracted the monoliths from the quarries of Syene, and transported them to Thebes, and partly incised the hieroglyphs of the middle column. His brother and successor, Sesostris, whose reign began 1328 B.C., completed the inscriptions. It thus appears that the hieroglyphs were executed before the erection; for Ramses II. set up the obelisks 1388 B.C., and had his name engraved on the base as an historical record. The total height of the shaft is 75 feet, at its base 8 feet wide, with an average of 5 feet in width. In its elevation the opposite faces in their height have a different curvature,—on the one side being convex and the other concave, to the extent of about a couple of inches, an imperceptible difference from a straight line; but it is remarkable that the two obelisks coincide in this detail. I imagine that the first block must have been irregularly marked out and worked, and the second one compelled to follow the faulty line in the quarry. The pedestal of each obelisk is composed of two distinct parts, its base and its die. The base or plinth resting on the pavement consists of three horizontal blocks of three courses of sandstone; the central die is a granite monolith, supporting the weight of the obelisk, and has on two of its sides four projecting monkeys in high relief, the other sides being plain, with the exception of incised hieroglyphs. One side of the die with four of the monkey figures was a slab-facing of the die, and it consequently did not contribute to its solidity. The entire monument was erected on a gray stone paving, and was sunk into the paving-blocks a few inches. Such is the very remarkable construction and decoration of these, I presume, very exceptional instances. As to the pedestals of the obelisks, we may infer that in other cases the monoliths rested on one or more steps, and that they did not rise at once without any superstructure or plinth from the level of the pavement. Sometimes bronze balls or other supports at the angles raised the monolith a few inches above the slab or block beneath. Mr. Dixon discovered an inscription engraved in

Greek and Latin on the bronze crabs supporting the standing obelisk of Alexandria, having the words "Anno VIII. Cæsaris, Barbarus Præfectus Ægypti posuit; Architectore Pontio" (see Erasmus Wilson's "Cleopatra's Needle," p. 11). This explains the reason why some of the obelisks at Rome have the like angular supports.

The erections on the banks of the Nile were constructed of the sand and limestones extracted from the quarries near. The pink granite was only used for the obelisks, statues, sarcophagi, casings of the pyramids, sanctuaries in temples, and linings of some special tombs, and for other precious or sacred purposes. The position of the quarries of Syene must have been of the utmost importance in facilitating the application of that fine material. Situated below the rapids,—or, as they are generally called, the cataracts,—when once the masses were extracted from their beds, no obstruction presented itself in their course down the river to their destination, whether to Memphis, Heliopolis, or the Delta. Mr. W. R. Cooper states that twenty-seven of the forty-two obelisks now known were from Syene, and they are doubtless the largest. An unextracted block still remains at Syene, 95 feet long by a diameter of 11 feet, with the quarrymen's marks upon it. Sir Gardner Wilkinson mentions that the final operation of extraction, when three sides of a mass had been worked round, was by cutting a groove or channel about 2 inches in depth, and kindling a fire along its whole length. When the stone was intensely heated, cold water was poured into the groove, and the block detached itself with a clear fracture. Wedges of wood were also inserted, saturated with water, then exposed to heat, and the expansion rent the mass asunder. Thus detached, it was drawn down to the river, where it was encased, or upon a gallery or raft floated down the Nile to near the spot where it was ultimately to be set up. From the river-bank it was hauled to the propylæ in front of which it was to be erected. We have no hieroglyphs or paintings on the walls of the pyla or tombs showing how the obelisks were raised and placed in their final position. That the erection of the monolith on its pedestal was a most critical operation is

sufficiently obvious, and its difficulty is illustrated by an anecdote related by Pliny:—Ramses erected an obelisk 140 cubits high and of prodigious thickness. It is said 120,000 men were employed on the work. To insure the safety of the operation by the extremest skill of the architect, he had his own son fastened to the summit while it was raised. On a small illustration before you there is represented a mural painting in a hypogæe, or underground tomb, at Gournah, with three men polishing a column of no great size; but that may be conventional. The column rests on blocks; the polishers are astride, or seated on the column, with rubbers rubbing the surface. Another, from the same tomb, shows a colossal upright figure surrounded by scaffold-poles; five artisans are chiseling, rubbing, and polishing the surface. Another small illustration represents a mason carving a many-colored sphinx; he is chiseling the paw of the animal; he has a wooden mallet in his right hand, and in his left a steel chisel, unmistakably indicated by the deep blue color of the tool. We know not whether emery or what other powder was used by the polisher.

I have not yet alluded to the masons' and carvers' operations of cutting the hard materials used in their obelisks, statues, sarcophagi, &c., such as the pink and black granite, black marble, basalt, &c. Hardly any iron tools have been preserved among the relics of the tombs. With what materials did the ancient Egyptians carve with such refined delicacy and exquisite sharpness the mouth, eyes, and other features of their statues, or what Mr. Erasmus Wilson calls the gem-like surfaces of the *in cavo relievo* of the hieroglyphs? I do not know that we are possessed of any process by which brass may be sufficiently hardened for the purpose, and we have not specimens enough which have survived the oxidation of the iron to satisfy us on the point as to that material. Could they prepare and soften the surface by some chemical application on the harder elements of their hard stones? No one as yet has been able to inform us; but the secret mystery of the execution of the Egyptian sculpture still evokes our wonder and admiration of their skill. Our own granite merchants

have achieved wonders, by means of steam machinery, in working out by rotary motion the shafts and bases and caps of certain columns and circular pedestals; but the refined sharpness of the lips, eyebrows, and other delicate features of the Egyptian heads, as they appear even upon the lids of the sarcophagi or the busts in the British Museum, has yet to be attained.

I have before observed that the Egyptians were less careful as regards any fixed proportions of their monoliths, but were more anxious to use up the blocks as they came from the quarry, whether as to the height or uniformity of shape. The sides of an obelisk rarely corresponded exactly to the breadth of its face, or the height of the shaft to any fixed relation with the width at the base; and there is a like disregard in the height of the pyramidion, which, however, was high-peaked, and never stunted. Nevertheless, we may generally assume that the shaft varied from eight to nine diameters high up to the pyramidion, which was from sixty to seventy-five hundreds of the breadth at the base. Too few of the pedestals, plinths, or steps have been ascertained or measured to afford any general law of proportion, whether as to their breadth or height.

The positions of obelisks were before the gigantic pylons, which formed the entrance gateways to the forecourts of their temples, and they were, I think, without exception, always in pairs. At Karnak the situation of the two lofty ones erected by Queen Hatasou (one of which still stands, and is, according to Mariette Bey, 108 feet 6 inches high, the loftiest one known) was between two lofty pylons only 40 feet or 50 feet apart! Those in front of the outer pylon are not so distant in advance of it. Consequently the Egyptians disregarded the immediate proximity of a lofty wall backing them up, and none are known situated in wide open spaces. I have grouped together in a drawing the various objects which occupied the approaches to the temples and formed an assemblage that was calculated to impress with awe the dignity of the fane of their god. The sacred way led up from the river, flanked on each side with variously headed sphinxes. At Karnak

the dromos is one mile and one-third long, with a line of sphinxes on each side. Approaching nearer, the worshipper finds two obelisks on the right and left, not necessarily of the same height. At Luxor one is 7 feet or 8 feet higher than the other, and to diminish the appearance of disparity in size, the shorter one is raised on a lofty pedestal and brought some feet in advance of its companion. Attached to the face of the pylon are six sedent gigantic statues of kings, majestic as to size, and seated in the hieratic posture. Lofty colored poles, similar to the standards at Venice, are inserted in sinkings chased into the walls, surmounted with the expanded banners of the kings or heraldic bearings of the temple floating in the wind. The pylon itself, perhaps 200 feet wide and 100 feet high, forms the back-ground of the whole, crowned by its cavetto cornice, and its surface covered with colored sculptures of the victorious Ramses, in his chariot, with upraised arm slaying his enemies, trampling them under his horses' hoofs, and also dispersing them in flight,—a grand scene of one of the dramas in the reign of a victorious monarch. In the center of the structure is the portal, 56 feet high, and through it the sacred or triumphal procession in all its gorgeous majesty to within the sacred precincts, there to observe the ritual ceremonials of the mysterious Egyptian cult of one or more of their eight great divinities or animal gods.

Having thus given a slight sketch of the architectural magnificence of the Egyptians, allow me to offer a tribute of respect to a brother architect: his name, as given by Mariette Bey, is inscribed on the Temple of Edfou. It was Ei-em-hotep Oer-si-Phtah Imouthes, the great son of Phtah, the only one yet discovered on the monuments of Egypt. I am afraid we are too late for its insertion in the colossal Architectural Dictionary of our time, unless it finds its way into an appendix.

The chronology of the Bible, as assumed by some learned men, gives the age of the world before the Christian Era as 4004 years. Mariette Bey (p. 22) *under reservation*, founding the calculations upon dates afforded by inscriptions upon tombs, temples, obelisks, and other monuments, gives the date of

the Egyptian empire alone and its dynasties as 5004. Bunsen assumes a still remoter period, and my friend Lesueur, our Honorary and Corresponding Member, in his "*Chronologie des Rois d'Egypte*," commences with 20,000, which latter is to be considered as an imaginary datum from which to start in computing the history of the world. But adopting Mariette Bey's comparatively moderate number of 5004 for the beginning of the Thinite dynasty, as the historic date of the commencement of Egypt's national existence, it fills one with wonder when we consider how many gaps occur in the continuous rule of Egypt's autonomy. How could the very existence of her nationality and arts be maintained, even with periods of more or less purity, when we know that for about 1,200 years, or nearly one-fourth of her existence, she was at various times ruled and overrun by the hykshos or shepherds, the Ethiopians and the Persians, under Cambyeses, Darius, and Xerxes? At last she was conquered and ruled for 332 of those years by the Greeks and Romans—from the time of Alexander and his successors to that of the Romans. Could any other people under such crushing circumstances have maintained their identity on their own native soil?

I cannot but think that the arrival and erection of the Alexandrian obelisk

among us may produce very notable results in regard to our knowledge of ancient Egyptian history, connected as it is with our Bible. The old Greeks and Romans, the classics of our boyhood, have had their annals duly chronicled and reduced to elaborate histories by the learned. These, it is true, have been turned upside down by recent erudite inquiries, substituting a different and new chronology, and an assumed rational statement of facts. Egypt till very recently had no consecutive accepted history in our language, that I know of, until our learned Dr. Birch, of the British Museum,—a name honored and esteemed by all Egyptologists, whether British or foreign,—compiled for the Christian Knowledge Society his summary of the ancient history of Egypt from the monuments, putting together with vast knowledge and most critical acumen an admirable history. There cannot be a doubt that our countrymen, as they pass by our obelisk, will have their curiosity excited by the sight of hieroglyphs which may have been seen and read by the Jews in the time of Moses, or when our Saviour was taken by his parents to Egypt as a place of refuge from Herod's rage. They will seek in Dr. Birch's book the solution of the mysteries revealed in those enigmatical sculptures, and the history of that ancient people.

## STEEL PLATES.

From "Engineering."

THE most accurate knowledge of the ductility and other mechanical properties of a plate can be gained by testing to destruction a strip cut from it, and this is the only method to use when we require to compare the ductility and tenacity of two or more samples with any degree of exactness. It is almost needless to say, however, that the expense of carrying out this method, with anything like the accuracy necessary to be of real service, must prevent its being adopted by all but a very few boilermakers and shipbuilders. Fortunately, however, in order to enable the user to satisfy him-

self of the suitability of a steel plate for any purpose for which he may require it a simpler and much less costly test is in most cases sufficient. This is what is well known as the "temper test," and consists of heating the strip of plate to a bright red and plunging it into cold water and then bending it cold. The range and suddenness of the change of temperature in cooling and the degree of consequent bending the plate will serve to indicate its quality with respect to ductility and soundness. The Admiralty temper test for steel plates is as follows; "Strips cut lengthwise of

the plate,  $1\frac{1}{2}$  inches wide, heated uniformly to a low cherry-red and cooled in water of 82 deg. Fahr., must stand bending in a press to a curve of which the inner radius is one and a half times the thickness of the plates tested." Lloyd's Register temper test for ship and boiler plates is practically the same as this.

We may here remark that, however valuable this temper test may be and in our opinion actually is, it is by no means an absolutely accurate test, since by skillful manipulation and allowing plenty of time for the operation, one smith can make a strip pass a given test where another will fail to do so. When the bending is done by hammering in the ordinary way, the degree to which any given plate may be made to fold back upon itself depends greatly upon its temperature and upon the direction, position, and intensity of the blows on its surface by which the bending is effected.

When a steel plate is tested for its tenacity the tensile test is made in order to ascertain whether the tenacity is not over a certain limit, rather than that it is not under this limit, and in order to ascertain the amount of elongation, the object being to determine whether the ductility is sufficient to insure absence of liability to harden locally by tempering, shearing, punching, and smithing, and sufficient not to allow cracks to spread quickly and without warning, a drawback possessed by steel and a consequence of its homogeneity. The temper test is certainly a more direct method than the tensile test of ascertaining the suitability of the material for smithing and bearing sudden cooling, while it is equally as good for judging of the other qualities, where an exact comparison is not required. It is not surprising then that the makers of steel plates use this simple temper test largely. In fact they are understood to apply it to every plate that is rolled at the present time, so that the quality of all steel plates is now pretty well insured. How long they will continue to do so it is impossible to say, but when they become more certain of the quality of the material, it is probable that the giving up of the testing of every plate will be one of the first steps towards reducing the cost when competition is keener than at present, and

leads to a lowering of prices. The accumulation of test specimens must be already very large at some of the manufacturers, and it can hardly be expected that makers will long continue to mark the bent test shearings with the same number as the plates from which they are cut, and preserve them for the purpose of comparison in the event of the plates turning out brittle, as is suggested in Lloyd's Committee's report on steel for shipbuilding.

We have dwelt at some length on the value of this temper test, in consequence of hearing not long ago, at a meeting of engineers and shipbuilders, a learned professor, whose name is well known amongst naval architects, ask in an elated manner what is the value of a hot test for ship plates, for of all places in the world a ship's bottom is the least likely ever to get red hot. Had this remark come from a less enlightened source and not been received with evident satisfaction by a number of engineers and shipbuilders, it would have appeared unnecessary to say that the test was designed to prove the suitability of the plates for the treatment they received previous, as well as subsequent, to their immersion when riveted in their place.

It is well known that iron plates of any given quality are injured by punching to a greater degree as they increase in thickness. There is unfortunately a lack of experiments to show the relation between the amount of injury and the thickness of the plate. Ductile steel plates are affected in a somewhat similar manner. The thicker the plate the greater the loss of strength due to punching, and a series of experiments to determine these amounts for different thicknesses is very much wanted. With steel plates of even 26 tons tenacity and unannealed after punching, the damage as regards extension stress done by punching compared with drilling increases rapidly with the thickness of the plate and the hardness of the material. There is, however, this difference between punched steel and iron plates, that the tensile strength and ductility of the former can to a very great extent be restored by annealing, whilst the same process has comparatively little effect in restoring the strength lost in punching

iron plates. The loss of strength in a plate  $\frac{1}{4}$  inch thick, punched and unannealed, may be two per cent., in a  $\frac{1}{2}$  inch plate 15 per cent., and in a 1 inch plate over 30 per cent., the solid plates of the different thicknesses having the same tenacity and ductility. By annealing these plates after punching these losses may be reduced to from 2 to 5 per cent. in the thicker plates. With a harder steel, say of 32 tons tenacity, the damage in  $\frac{1}{4}$  inch plates unannealed would be almost 5 per cent., in  $\frac{1}{2}$  inch plates 20 per cent., and in one inch plates 40 per cent. By annealing the loss may be reduced to what we have given for the softer plates. It is thus seen, as regards the injury done by punching that when the plates are annealed the stronger plates may not suffer more than those of inferior tenacity and greater ductility.

The damage sustained by the plate in punching increases not only with the thickness of plate but also with the increase of ratio of thickness of plates to diameter of punch. In practice this ratio increases rapidly with the increase of thickness of plate, and this is mainly the reason that thick plates suffer so much more than thin ones. By making the die large in proportion to the diameter of punch and by keeping the point of the punch rather concave than convex and the punch and die in good order, the damaging effect of the punching can be reduced to a minimum for any given ratio of thickness of plate to diameter of punch. The American spiral-faced punch, which has lately been introduced into this country, is also stated to injure steel plates materially less than ordinary punches and experiments lately made at Crewe by Mr. Webb appear to prove this. If, however, it be required to save more of the strength of thick plates of steel than many are content to save in the case of iron plates, the steel plates must be either drilled or annealed after punching.

Since the endeavour to obtain a low tenacity in steel plates, which we have advocated, is partly with a view to insure sufficient ductility to enable them to be smithed and punched without the necessity of subsequent annealing, and since there is a limit to the thickness of plate that can be punched for ordinary

sized rivets without the plate requiring annealing, it is evident that our attempts to obtain such a ductility as will render annealing after punching unnecessary should be limited to a certain thickness of plate. What this limit of thickness it cannot at present be decided, but it will probably be  $\frac{7}{16}$  inch and possibly  $\frac{1}{2}$  inch. This thickness includes nearly all plates for ordinary boiler and shipbuilding work, but does not extend to tube-plates and the shell plates of marine boilers.

If a low tenacity were required in plates to enable them to be punched for boiler-making only, we might be inclined to say let all plates for boiler making be drilled and a higher degree of tenacity be maintained, but as the low tenacity is required to insure ductility, which is affected by other processes than punching, and as the expense of drilling would tend to retard the general adoption of steel plates for shipbuilding and girder work it is advisable to insist upon obtaining the lowest tenacity compatible with uniformity and soundness of material as long as a low tenacity can be taken as an indication of a high degree of ductility.

Steel subject to stresses of varying intensity shocks, or vibration, is liable in time to lose its granular structure and to become crystalline and consequently brittle, pretty much in the same manner, although perhaps not to the same degree, that iron becomes brittle under similar circumstances. It is extremely probable that the tendency to become brittle decreases as the amount of ductility possessed by the material is increased in the first instance, and although there are not yet sufficient results gathered from experience to decide this question one way or the other, yet the presumption is so strong that the tendency to become brittle is inversely proportionate to the amount of ductility, that it appears justifiable to adduce this as a further argument in favor of attaining the greatest amount of ductility practicable.

There are very few purposes for which steel plates are used that ductility in itself is not a positive advantage. For all ship plates, for boiler shells furnace tubes, and tube plates, ductility and non-liability to temper are all im-

portant. It is perhaps only when used for flat surfaces, strengthened with screwed stays, and especially those simply rivetted over at the ends and not provided with nuts, such as most locomotive firebox plates and the flat plates in many combustion chambers and back ends of marine boilers, that the ductility may be regarded as a source of weakness, and for the following reason. The tendency of a flat plate to bulge under pressure and the amount of bulging that takes place are proportionate to the ductility of the material. As the resistance of a flat surface strengthened by screw stays without nuts depends greatly upon the hold of the threads, and as this hold is loosened by the bulging, it follows that a material like very soft steel may be less able to resist a given static pressure than an inferior iron plate that has both less ductility and less ultimate tenacity or a lower limit of elasticity. The resistance of a boiler plate to bulging, so far as its practical value is concerned is to be measured by its stiffness when stayed, rather than by its ultimate tenacity. Of two plates of a given thickness and stayed in a similar manner, that having the greater tenacity and ductility will no doubt bear at the apex of the bulging a greater bursting pressure, but for all practical purposes it may be the weaker plate of the two, and require additional stiffness by having the stays pitched closer.

The most eminent authorities on the strength of materials in treating of the strength of flat stayed plates, regard the plate between the stays as a beam, and consequently consider that its strength varies as the square of the thickness, and assume that this rule holds good alike for cast iron, wrought iron, steel and copper, by merely altering the coefficient of strength for the different materials. This rule of the strength varying as the square of the thickness can, however, only be appreciable within a certain limit of the ratio of the span to the thickness and this limit becomes less as the ductility of the material increases. The limit has not yet been decided either by experiment or theoretically for different materials, but the rule probably holds good for steel and iron plates where the distance between

the stays does not exceed twenty-four times the thickness of plate. Any reduction of thickness in virtue of the greater tenacity of steel plates must be attempted with great caution in substituting soft steel for iron plates in flat-stayed surfaces. For instance, if we assume the tenacity of the steel and iron to be respectively 28 and 21 tons a  $\frac{3}{8}$  inch steel plate will be equally as strong as a  $\frac{1}{2}$  inch iron plate in tension. This is equivalent to a reduction of 25 per cent. in thickness, but for a flat surface a reduction of only about 13 per cent. can be allowed in the thickness of a steel plate, in order to preserve an ultimate strength equal to that of the iron plate, so that  $\frac{1}{2}$  inch iron cannot be replaced by anything less than  $\frac{7}{16}$  inch brae in steel. As the more ductile steel will commence to bulge before the iron plate, and sooner take a permanent set, with the above relative dimensions, it is questionable whether even this small reduction of thickness can be allowed.

Then when we come to the question of durability, if we assume the steel to corrode as fast as the iron plates, it is certain that we cannot allow even the above slight reduction in thickness if we require the steel to last as long as the iron, assuming the plates to be allowed to waste till they each have the same proportion of strength to that they originally possessed. By reducing the pitch of the stays, in order to obtain equal strength with a thinner plate, we add to both the weight and expense, and possibly increase both till the advantages of using a thinner plate vanish altogether, save where the reduction of thickness is required to facilitate the transmission of heat and prevent overheating at the joints. For locomotive firebox and marine boiler combustion chamber plates, no greater stiffness in the material itself at the expense of ductility can be recommended for the purpose of allowing a lighter plate to be used, since the greatest amount of ductility is required to prevent cracking at the stay holes and between the stays. No further evidence on this point is necessary than the fact that costly thick copper plates are still considered in this country the best material for locomotive fireboxes, notwithstanding the numerous

attempts to use thinner plates of steel and iron instead.

It appears to us that although Lloyd's Committee in their report on steel for boiler-making, allow twelve per cent. diminution of thickness when steel plates are used for flat-stayed surfaces subject to a bulging pressure, the nature and tenacity of the material itself scarcely justifies even this small reduction when

the steel is very soft. We do not mean to say, however, that it is imprudent to allow this reduction, any more than it would be imprudent to allow it in a great number of cases for iron plates. The difference in strength for all practical purposes between good and indifferent workmanship often amounts to over twelve per cent. in flat surfaces of the same thickness and pitch of stays.

## DECIMAL AND OTHER ARITHMETICAL NOTATIONS.

By FREDERICK BROOKS.

A Paper read before the Boston Society of Civil Engineers, April 17, 1878.

THE magnificent New Palace of Westminster, in which are the British Houses of Parliament, may be regarded as a monument erected in honor of our arithmetic; for it was built to replace the old Houses destroyed in 1834 by a conflagration which was kindled by the burning of the notched sticks, or tallies, formerly used in keeping accounts. From before the Norman conquest down to 1782 this barbarous practice was maintained in the British Exchequer, similar to our treasury; and the tallies of seven centuries made a considerable wood-pile. The English found this method of keeping the national accounts such a perfect success that, after the union with Scotland in 1707, they actually sent a lot of hazel rods to Edinburgh for the officers there; but the Scotchmen, unable to appreciate their convenience, put them aside as useless lumber, and persisted in keeping their accounts in writing. The English, to be sure, had also some records in writing; they were kept in Latin, and numbers were expressed by the Roman numerals, I for one, V for five, X for ten, L for fifty, and so forth. Lord Granville was afraid that if this ridiculous book-keeping should once be abandoned nobody could understand the ancient records. So blindly are our British brethren attached to old customs that it was not until 1831 that the Committee on Public Accounts ordered the immediate abolition of the mediæval system, and the

adoption of the English language and the Arabic figures, so called. The old tallies were ordered to be burnt. In the execution of this order, in the stoves used for heating the House of Lords, the building was set on fire and both Houses of Parliament were consumed.

Into the other parts of Europe, outside of the British Exchequer, decimal arithmetic was introduced toward the close of the Middle Ages. It is supposed to have originated in India, but we received it at the hands of the Arabians and Moors. The grand peculiarity of it is that the value of each figure depends upon its position, and an additional character is devised, namely—the zero, to alter the position and consequently the significance of the other numerals by occupying space without itself denoting any number. Thus, moving a figure one place to the left increases its value ten times; two places, one hundred times; and so on in geometrical progression. The essential merit of the invention consists in this multiplication in a certain ratio; whether the ratio adopted as the base of the system be ten or some other number is a matter of secondary importance.

There would be some remarkable advantages in the use of two instead of ten. With such a binary arithmetic if we represent one by a full line and zero by a broken line we shall begin to count as follows:

1 one,  
 1 : two,  
 1 1 three, or two plus one,  
 1 : : four, or twice two,  
 1 : 1 five,  
 1 1 : six,  
 1 1 1 seven,  
 1 : : : eight,  
 1 : : 1 nine,  
 1 : 1 : ten,

and so on. In writing successively the above numbers we are adding one each time; if there is already one in the units' column, we "carry" one to the column of twos, and make a zero mark in the units' place; if there is also already one in the column of twos, we make another zero mark there, and carry one to the column of fours, &c. &c. Thus, only two different characters are required to represent all numbers. So there is no multiplication table necessary to be learned; multiplication becomes a matter of copying down figures, and requires no arbitrary memory of products; it is like multiplying decimally by 1, or 101, or any other number containing only zeros and ones. It is claimed that the binary notation affords superior facilities for investigating the properties of numbers, as we may more readily understand by examining some arithmetical series. Look at the units' column of the series of natural numbers which we began to write above; it contains ones and zeros alternately; reading down the next column we have two ones, then two zeros, then two ones, then two zeros, and so on. In the third column we have, or should have, four ones and four zeros; the next column goes by eights. As another illustration take the series of squares given below:

1	1
1 : :	4
1 : : 1	9
1 : : : :	16
1 1 : : 1	25
1 : : 1 : :	36
1 1 : : : 1	49
1 : : : : :	64
1 : 1 : : : 1	81
1 1 : : 1 : :	100
1 1 1 1 : : 1	121

In the units' column there is alternation; the next contains zeros only;

reading down the third column we have one, and three zeros, one, and three zeros, successively; the next column has a period of eight figures; by extending the table the law of repetition might be traced further. In this, the binary notation differs from the decimal merely in the frequency with which the periods return. Where the binary figures come back with every second, fourth and eighth number in the series, the decimals wait for the tenth, hundredth and thousandth. In the decimal squares above, if we begin at 25 and read the units' column either upward or downward, we find 5, 6, 9, 4, 1. Those figures and the zero which follows them are repeated in the same order throughout the series; no square can end in 2, 3, 7 or 8.

Binary notation is not recommended for ordinary purposes on account of its requiring so many figures to express even the smaller numbers, which are the most frequently used. Five places of figures will take us up to the number thirty-one; to denote thirty-two or more requires as many as six places. The same degree of accuracy which we now obtain by the use of seven places of decimals, in our Briggs logarithms for instance, would require twenty-three places of the binary notation. In adding up a column of but moderate length, for example the numbers written above, the sum of a single column is likely to be a number which occupies three places, so that after setting down one we have still two places to carry; whereas in adding ten numbers of our common decimal arithmetic, the largest amount we could possibly have in any one column would be ten 9's making 90, or one figure to set down and only one figure to carry.

The binary arithmetic is a device of the great Leibnitz, who divides with Sir Isaac Newton the honor of inventing the differential calculus. He circulated the knowledge of it somewhat freely; and a Jesuit missionary in Pekin, who learned of it, thought that in it he discovered the key to some lines suspended in all the Chinese temples, and supposed to be of great antiquity and mysterious meaning. These lines are called the Cova of Fohi, and are usually placed around the sides of an octagonal space. By putting them all parallel they ap-

pear as here shown. The interpretation suggested is that they express in binary notation, zero, one, two, three, four, five, six, seven.

			Zero.
			One.
			Two.
			Three.
			Four.
			Five.
			Six.
			Seven.

I have dwelt at some length on the binary arithmetic, partly on account of its interesting and unique qualities, and partly for the sake of more easily enforcing the wide difference there is between the immutable relations of numbers and the peculiarities (we might almost say the accidents) of any particular method of writing them. For example, we say that twice nine is eighteen; and we cannot conceive it to be anything else. We can write the fact in binary arithmetic as well as in any other; and we can illustrate it to a child or a savage with whom we cannot communicate in any language, by taking eighteen pebbles or counters and arranging them in two rows with nine in each row. If, on the other hand, we set down 18, as usually written, and remark that the sum of the digits, 1 plus 8 equals 9, we are dealing with a peculiarity of the decimal method of writing, an interesting and valuable property, but one which does not exist in the binary arithmetic, and would not appear to a child playing with eighteen counters. We sometimes hear it said in a careless way, that there is a very curious thing about the number 9, namely, that in all its multiples the sum of the digits is divisible by 9; now that has

nothing whatever to do with the abstract number nine; it merely results from the fact that one plus nine, which is ten, happens to be the base of the established system of numeration. We are so constantly using this system in all our numerical operations, and our thoughts of number are so completely identified with this method of representation, that it is difficult for us to separate our ideas of number from the Arabic figures, even when we have some other notation before our eyes. This is just as it should be; it is, indeed, inevitable; but it makes the suggestion of substituting some other notation for the decimal all over the world seem appalling. That would amount to providing new brains for the entire population. It requires some little time for a person with no more than the ordinary mathematical training to comprehend even what is meant by an alteration of our arithmetic. To alter our arithmetic, moreover, would require us to alter the records of the past for several centuries, or else it would put upon the shelf the accumulated knowledge of the race so far as it is expressed in numbers. It would embitter the lives of one whole generation.

But whatever may be thought of its practical application, it is at least an entertaining study to compare the merits of the different bases which have been recommended for arithmetical notation. Our present foundation is ten; not because of its advantages for civilized purposes, but simply because man has ten fingers and ten toes, and in the naked childhood of the race they constitute a portable mathematical library. Nearly every language spoken on this planet bears witness to the primitive tendency to number by tens; for words are many ages older than the present arithmetic. Taking as a single illustration our own mother tongue, eleven means *leave one*, twelve means *leave two*, that is, after disposing of ten; thirteen, fourteen, fifteen, &c., and our twenties, thirties and forties are of unmistakable significance. These names, by the way, would be so much more to alter, if the attempt were ever to be made to abandon decimal arithmetic.

Natural as it is for men to count on their fingers, that is of little importance now; and it is equally natural for men

to subdivide things by successive bisections. A favorite illustration is the practice in the stock market of quoting prices by per cent. and half, quarter and eighth of a per cent., where it would be more consistent to divide one per centum into ten parts instead of eight. In this month of April, 1878, some Boston brokers were weak enough to sell ten bonds of a thousand dollars each at a premium of four per cent. and three-eighths, a sixteenth and a thirty-second, making the total price \$10446.875. One might imagine that they had been apprenticed to a carpenter in boyhood. Anything flexible like a cord or a piece of paper can be folded double, then doubled again, and again; whereas it is not so easy to put it into three or five folds.

There are valuable properties about a binary series; for instance a set of weights of the series 1, 2, 4, 8, 16, 32, &c., is that which forms the greatest range of combinations with the smallest number of pieces and the least total weight of metal. One-half is .5; one quarter, .25; one-eighth, .125; each halving requires an additional decimal place to express it. For the sake of greater convenience in writing these commonest fractions the base of arithmetical notation, instead of being ten, might better have been some number divisible by four. An odd number would be entirely out of the question. Several numbers divisible by four are given below, with the length of multiplication table required for each as a base, that is, the number of products which would have to be arbitrarily remembered. For comparison ten is also included in the list.

Base.	Number of Multiplications.	Modulus of Logarithms.	Places of figures required to express one ten-millionth.	Largest number that can be written with three figures.
4	3	0.7213	11.63	63
8	21	0.4809	7.75	511
10	36	0.4343	7.00	999
12	55	0.4024	6.49	1727
16	105	0.3607	5.81	4095
20	171	0.3338	5.38	7999

on each of the numbers in the first column is added as a measure of the places of figures required in each arithmetic. Perhaps the next column will be more readily understood, in which is shown how many figures would be necessary to give the degree of accuracy that we now get with seven decimal places. It is computed from the third column simply by dividing by 0.4343 and multiplying by 7. The last column shows how many numbers could be written with three figures or less, being one less than the cube of the base.

A glance at the table is enough to throw out four as too small and twenty as too large. With four as a base we should write about five figures for every three figures that we write now; all the multiplication table we should need to remember would be twice two is four, twice three is six, three times three is nine; but the human mind easily soars higher than that. If twenty were our base we could get along with writing about three-quarters as many figures as we now do; but should have to learn nearly five times as much multiplication table. Eight, twelve and sixteen will bear further examination. They do not vary so very widely in the number of figures they require us to use; but the smallest number has a great advantage in the shortness of its multiplication table. Some other considerations are more favorable to the larger numbers.

To my thinking, the decisive difference between eight and sixteen on one side and twelve on the other is divisibility by three. The fraction one-third cannot be expressed by an arithmetic of eighths and sixteenths any better than by decimals; yet it is often desirable, if we may judge by the frequency with which we stumble upon  $33\frac{1}{3}$  and the like in decimal computations. Three is a small number and is therefore much used. We have three kingdoms of nature, three powers of the federal government, three years as a term of office, three primary colors, and so on to an indefinite length. Sometimes also there is special reason for a threefold arrangement; everything that occupies space must have three dimensions; in counting out coins or other small articles it may be found that three at a time are handled with the greatest facility; in case of a contro-

The modulus of logarithmic tables based

versy between two, a third may be added to reach a decision, as when we have three games in a rubber or three members on a board of arbitration. The fact that twelve is a multiple of three I regard as the one sufficient reason for preferring twelve to eight or sixteen as a base of arithmetic; and this in spite of its requiring two and a half times as much multiplication table as eight would. It should be observed that in teaching arithmetic at school now, instead of stopping with nine

times nine is eighty-one, children learn the multiplication table up to twelve times twelve; and they would learn the same extent of table still more easily, probably, if they were taught only duodecimal arithmetic instead of decimal. To appreciate this point let us examine the following duodecimal multiplication table, in which, as the simplest way to avoid confusion, the letters of the alphabet are used for the required eleven integers.

One.....	A	B	C	D	E	F	G	H	J	K	L
Two .....	B	D									
Three .....	C	F	J								
Four .....	D	H	AO	AD							
Five.....	E	K	AC	AH	BA						
Six.....	F	AO	AF	BO	BF	CO					
Seven .....	G	AB	AJ	BD	BL	CF	DA				
Eight.....	H	AD	BO	BH	CD	DO	DH	ED			
Nine .....	J	AF	BC	CO	CJ	DF	EC	FO	FJ		
Ten .....	K	AH	BF	CD	DB	EO	EK	FH	GF	HD	
Eleven.....	L	AK	BJ	CH	DC	EF	FE	GD	HC	JB	KA

The multiples of six (F) all end in six (F) or zero, just as now multiples of 5 end in 5 or 0. All multiples of four (D) and eight (H) end in four (D), eight (H), or zero; whereas now they may end in any even number. All multiples of three (C) and nine (J) end in three (C), six (F), nine (J) or zero; whereas now they may end in any number. Two, seven and eleven present about the same degree of convenience or inconvenience as now. Five and ten, of course, lose in the duodecimal arithmetic the simple appearance which they now present. The relations here pointed out would enable us to tell by inspection something about the divisibility of numbers, and a little study of this matter may assist us in judging just how much and how little the advantages of a duodecimal arithmetic amount to. Any number ending in zero would be divisible by two, three, four, six and twelve. If the last figure in a number were divisible by two, three,

four or six, the number itself would be likewise divisible. If the last two places were divisible by eight, nine, sixteen or eighteen, the whole number would be likewise divisible. If the sum of the digits (begging pardon for the word) were divisible by eleven, the number would be divisible by eleven. We could not judge by inspection as to divisibility by five and seven; nor by ten, except that an odd number would certainly not be divisible by ten. By reading across the table diagonally we notice that the successive squares end in one (A), four (D), nine (J), four (D), one (A), zero, and so on repeating.

I base no argument on the common practice of dealing in dozens, grosses and great grosses; for it would be perfectly feasible to change the practice. When separate articles are sold by number, you can buy whatever number you please. There is no reason in the nature of things why sixteen eggs or sixteen

bottles of wine might not be sold instead of a dozen; no reason why ten men might not sit on a jury as well as any other number; and no reason why a washer-woman might not be paid for eight pieces as promptly as for twelve.

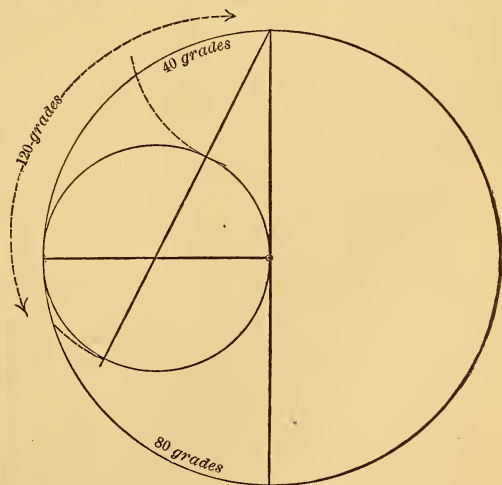
There is one thing to which the duodecimal arithmetic appears to be peculiarly adapted, and that is the division of the circle; nevertheless more stress is frequently laid on this point than it will bear. Let us consider the different ways of reckoning angles which are now used.

1. We have in the first place the mariner's compass which beautifully illustrates the method of continual bisection, coming down to the quarter point, which is  $\frac{1}{128}$  of four right angles. I presume this is found to be very convenient.

2. In mathematical computations we often have to reckon by the length of arc in terms of radius taken as unity. This method is called for when we have expressions involving both an arc and its sine or other trigonometric function. A semi-circumference is  $3.14+$ ; a quadrant is half as much, or  $1.57+$ ; the unit being an arc as long as the radius, is rather more than five-eighths of a quadrant. It would be possible to divide up this unit decimally, and to compute trigonometric tables entered with the sub-divisions. For special purposes there would be some convenience in such an arrangement. Suppose that I am required to lay out a circular curve connecting two tangents, and to determine the true length of the curve, the radius being given or assumed. That is a common problem enough. Let me have an angular instrument graduated in the way described, and let me measure with it the angle at which the tangents intersect. I read off some decimal. The length of curve required is simply the product of that decimal multiplied by the radius; and if the radius is assumed to be a round number like 100 or 1,000, the multiplication is reduced to fixing the position of the decimal point. To establish the points of tangency and any other points on the curve involves nothing unusual in computation or field-work except the facility gained by the decimal subdivision on the instrument and in the trigonometric table. Aside

from a few exceptional uses, however, the arrangement here suggested would be outrageously bad. It is not a division of the circle at all; it simply measures length of arc by a unit not commensurable with the circumference. This would be fatal to its use for the general purposes of an angular instrument; the right angle would not be marked on it, and the graduation would not come round to the point from which it started; for the mark for 6.28 would fall short of a complete circumference, and that for 6.29 would exceed it, the length being 6.2831853, &c., &c., &c. It would also be fatal to its use in most computations; our ordinary trigonometric tables are computed for one eighth part of the circle, and the same absolute values are repeated over and over again in the other parts of the circle, though the algebraic signs vary in the different quadrants. If similar tables were computed based on this incommensurable unit, the exact circumference and quadrants would not appear at all, and the values would never repeat themselves from zero to infinity.

3. We have next the centesimal division, so-called, which fully recognizes the importance of the quadrant; for it makes that the unit, and divides it into 100 grades, each grade into 100 minutes, and each minute into 100 seconds. There is a propriety in the division of the circle on a decimal scale, because, as every one knows, the chord of one-tenth of the circle bears a peculiar relation to the radius. Draw a diameter across the circle.



Tangent to this diameter at the center of the circle construct another circle with a radius one-half the first. Connect the end of the diameter with the center of the smaller circle, and produce the line so that it cuts the smaller circumference in two places. The length from the end of the diameter to one intersection is the chord of one-tenth of the original circle, or 40 grades; to the other intersection, the chord of three-tenths, or 120 grades; the difference between the two is the radius. This property has its value to a draughtsman laying out a decagon or a pentagon; but it is not much of a reason for adopting a decimal system of circular measure for general mathematical purposes. A similar remark may be made about another well-known relation, namely, that the chord of one-sixth of a circle is equal to the radius. That this is ignored by the centesimal division is the standard argument against it. An inconvenience might appear to the student beginning trigonometry; he might find that the angle whose cosine is  $\frac{1}{2}$ , instead of being expressed by some round number, is 66 grades, 66 minutes, 66 seconds and  $\frac{2}{3}$  of a second. If in actual use there would be any serious difficulty arising from this source I have yet to learn what that difficulty is; and I have inquired of a maker of angular instruments, and of a gentleman who has had experience in astronomical observatories. It is also alleged against the centesimal division that it was abandoned after a short trial in the place where it originated. It is now used to a very limited extent; I have heard one or two things which indicate that it is receiving favorable attention in Germany; and it never was very widely adopted, though appropriate trigonometric tables have been published by Callet, by Borda, and by some others. So far as it can be said to have failed, it is not on account of any incongruity between decimal division and the properties of the circle. If, simultaneously in all civilized countries, the technical and other schools of high grade should make a business of teaching the centesimal division to the rising generation, as something which they would undoubtedly have to use in after life, no insuperable difficulty would be found in introducing it. It is comparatively a small class in the community that has to

use circular measure; and that class is specially educated, and intelligent enough to appreciate the force of arguments with regard to it. That at some future time concerted action among all nations will be perfectly feasible, may be inferred from the continual increase of foreign intercourse which is now so conspicuous, and the multiplication of international exhibitions, associations and conventions, political, social, commercial and professional. The leaders of opinion will simply have to show, when the proper time comes, that it is worth while to adopt the centesimal division, and I believe it will eventually come into general use.

Centesimal grades can be reduced to the common degrees by deducting ten per cent.

4. Astronomers divide the circle into twenty-four parts called hours, each hour into sixty minutes, and each minute into sixty seconds. In this form they generally record right ascension, terrestrial longitude, and another similar angular measurement. Thus, in the American Ephemeris and Nautical Almanac the longitude of Washington Observatory, West of Greenwich, is given as 5 hours 8 minutes and  $12\frac{3}{100}$  seconds. It is also given in two other ways, one of which is .2140323, that being the equivalent decimal part of one circumference, or, as the Almanac says, of one day. This kind of angular measure is evidently borrowed from the established division of time, with which it is closely related. When it is noon at Washington Observatory, it is 5h. 8m. 12.s.39 P.M. at Greenwich. So important is it regarded in cases like this to have the division of the circle correspond with the division of time that astronomers have trigonometric tables entered directly with hours and their subdivisions, rather than go to the trouble of reducing to degrees and then working with the common trigonometric tables. The year also, being measured by the circle which the sun appears to describe upon the celestial sphere, is directly associated with circular measure. Admitting then that the measurement of time and of the circle ought to correspond, is there anything about time in itself that calls for one subdivision rather than another? Sunrise and sunset, noon and midnight, naturally divide the day into four parts. The equinoxes and

solstices naturally divide the year into four parts. The moon's phases naturally divide the lunar month into four parts. I believe that is all. As one indication that the usual division of time is not fixed by necessity, it may be observed that in various parts of the American Ephemeris and Nautical Almanac we find decimals of a year, decimals of a day, decimals of an hour and decimals of a minute. The division of the year into months may have been suggested, as the name "month" implies, by the motions of the moon; but one lunation, that is, the time from new moon to new moon, is in fact but little nearer to one-twelfth of a year than it is to one-thirteenth; and it is far enough from either. Twelve lunar months are  $354\frac{4}{10}$  days nearly, or about 11 days short of a year.

5. We come finally to the common sexagesimal division, in which the sextant or one-sixth part of the circumference is divided into sixty degrees, each degree into sixty minutes, and each minute into sixty seconds. This agrees very ill with the mariner's compass, of which one point is  $11^{\circ} 15'$ , and one quarter point is  $2^{\circ} 48' 45''$ . It is not at all adapted (as no reasonable division can be) to expressing the arc equal to radius, which is  $57^{\circ} 17' 44''.8+$ . It marks the quadrants with the inconvenient figures,  $90^{\circ}$ ,  $180^{\circ}$ ,  $270^{\circ}$ ,  $360^{\circ}$ , thus enabling the computer to tell, with a little effort, what quadrant any angle is in, and giving him perpetual annoyance in subtracting from those awkward numbers, to get complements and supplements. It corresponds imperfectly with the division of time; for it has 15 degrees to 1 hour,  $15'$  to 1 m. and  $15''$  to 1 s. It does not harmonize with the measurement of the earth's surface. If it did, it would simplify the U. S. public land surveys, which are based on meridians and parallels determined astronomically. Seamen insist on making the minute of a great circle, or "knot," their unit of distance; we call (or mis-call) this a mile, although it is about 15 per cent. greater than our statute mile. The sexagesimal division has two alleged advantages; it makes the number of degrees in the whole circumference something not very far from the number of days in the year; and it emphasizes

$60^{\circ}$ , whose chord equals the radius. The effect of this is that the angle whose sine is  $\frac{1}{2}$  and the angle whose cosine is  $\frac{1}{2}$  are expressed in round numbers; though the angle whose tangent is 1, and cotangent the same, is  $45^{\circ}$ , rather an odd value. Basing circular measure upon such points as these, just like dividing the year into twelve lunations, or founding arithmetic on the ten fingers, was very creditable when these things represented the highest attainments of the human mind; but in the present state of science they seem very trivial. Getting within five or six days of accuracy is now like being grossly in error. As for the importance of the angle of  $60^{\circ}$ , a surveyor might happen to measure it once in a lifetime; but is continually turning off  $90^{\circ}$  for the corners of streets and buildings and other rectangular work. In computing he uses logarithms, and finds that the functions of  $60^{\circ}$  appear as irregular as the rest.

Unfortunate though we may deem it, the fact remains that the sexagesimal division was adopted ages ago, has been in use ever since, and is now universally known; and just that fact constitutes its essential advantage. Let us examine its history. The ancient geometers and astronomers, struggling with something similar to the Roman numerals, were much troubled by the various fractions that arose in their computations, and, in order to manage them more conveniently, introduced a scheme of dividing into sixtieths. As sixty has an extraordinary variety of integral factors, all the commonest fractions can be expressed by this system. One sixth of a circumference they divided into sixty degrees, one degree into sixty primes or minutes, one minute into sixty seconds, one second into sixty trines, one trine into sixty quaternes, &c. The chord of  $60^{\circ}$ , which is the radius, they divided similarly. Their computations were chiefly confined to arcs and chords, and this really constituted a system of arithmetic. Numbers from one to fifty-nine were represented by letters and combinations of letters, but sixty was the unit of the next order or denomination, and sixty times sixty the unit of a still higher order, and so forth. Thus numbers were expressed with a facility which approaches our present notation and is

vastly superior to the Roman. It required a multiplication table extending up to 59 times 59, which must have been really a table to be consulted and not carried in the memory. Nine letters were used to represent the first nine numbers; then, instead of using the same characters over again for the tens as we do, they took six more letters for ten, twenty, thirty, forty, fifty and sixty. That was as high as it was necessary to go, and it used up more than half of the alphabet. Sometimes, of course, quantities occurred in which some denomination was unrepresented; in that case the space was occupied with the next letter of the Greek alphabet, which was  $\omicron$  micron, or little  $o$ . For instance they wrote  $\alpha^{\circ} \omicron' \varepsilon''$ , just as we should write  $1^{\circ} 0' 5''$ ; and that is the reason why our present character for zero happens to be the letter  $o$ . The sexagesimal arithmetic is attributed (possibly on insufficient evidence) to Ptolemy, chiefly celebrated for his works on geography and astronomy, which continued to be standard text-books for about fourteen centuries. After that long term of service the sexagesimal division of the radius was given up. In 1541, sixty-five years after the death of Regiomontanus, his two tables of natural sines were published; one is to radius 6,000,000; the other, to radius 10,000,000 (or, as we should say, to seven places of decimals) is similar to our present practice. A cycle of sixty

years has been used in India; and the day has been divided into 60 guries, each gurie into 60 polls, and each poll into 60 twinklings of an eye. We divide the hour sexagesimally, though we have 24 hours in the day. For latitude and longitude in geography and for most angular measurements this reminiscence of the Dark Ages, the sexagesimal division, is still in use down to the second. That is now sub-divided decimally; though the incongruity of this modification is noticeable in computing; in taking the complement of an angle by subtracting two places of degrees from 90, two places of minutes from 60, two places of seconds from 60, and two places of decimals from 1.00, we have an embarrassing variety. For greater facility in figuring curves in the field it is not uncommon for engineers, neglecting degrees, to reckon in minutes and fractions of a minute. The astronomer observing the position angle of a double star sets it down in degrees and decimals. In short, people will have a division that corresponds with the prevailing arithmetic, in spite of the fact that the usual tables are calculated for a system that does not correspond with the arithmetic now established. The sexagesimal division of the circle would harmonize with a duodecimal arithmetic little or no better than it does with a decimal, as is shown by the following tabular statement:

## SEXAGESIMALS.

Unit.	Successive Divisions by Twelve.			Successive Divisions by Ten.		
	$\frac{1}{12}$	$\frac{1}{144}$	$\frac{1}{1728}$	$\frac{1}{10}$	$\frac{1}{100}$	$\frac{1}{1000}$
360°	30°	2° 30'	0° 12' 30"	36°	3° 36'	0° 21' 36"
90°	7° 30'	0° 37' 30"	0° 3' 7 $\frac{1}{2}$ "	9°	0° 54'	0° 5' 24"
60°	5°	0° 25'	0° 2' 5 $\frac{1}{2}$ "	6°	0° 36'	0° 3' 36"
1°	0° 05'	0° 0' 25"	0° 0' 2 $\frac{1}{2}$ "	0° 06'	0° 0' 36"	0° 0' 3 $\frac{1}{10}$ "

The sexagesimal division would harmonize much better with an arithmetic based on twelve, than it would with an arithmetic based on eight or sixteen; but as new tables would be required for either, this is of little importance.

After this prolix review of the whole subject of dividing the circle it is sufficiently evident that the use of twelve as

a base of numeration would be adapted to expressing in simple form one-sixth part of the circumference; but that this advantage is of exceedingly small consequence.

On the other hand, eight and sixteen have the advantage over twelve in respect to several points which are worthy of notice; although they do not seem to

me sufficiently important to overcome the argument from divisibility by three.

In the first place they give still greater facility than twelve for binary subdivision. With sixteen for a base, eighths and sixteenths could be expressed with a single figure as one-half is now decimally, and with two figures we could go down to 256ths. That is carrying the thing unnecessarily far; we should be tolerably well off with twelve as a base, which would enable us to write sixteenths as easily as we now do quarters, with two figures.

Another little peculiarity about sixteen as a base of numeration, and, of course, a base of logarithmic tables also, is that the logarithms of two, four, and eight would be expressed by a single figure; for

$2^4=16$ , that is,  $16^{\frac{1}{4}}=2$ , therefore  $\log. 2$  would be four-sixteenths.

$4^2=16$ , that is,  $16^{\frac{2}{4}}=4$ , therefore  $\log. 4$  would be eight-sixteenths.

$8^{\frac{2}{3}}=16$ , that is,  $16^{\frac{1}{3}}=8$ , therefore  $\log. 8$  would be twelve-sixteenths.

Another point of more consequence is that sixteen is a perfect square. We perceive the advantage which this would give when we apply our arithmetic to the measurement of surface. For instance, the land surveyor of our fathers, using a Gunter's chain, probably had a realizing sense of the area included in one square chain. When he sought to imagine for himself some smaller unit of comparison, supposing he had been brought up on an arithmetic of sixteen, the idea of one-sixteenth part of a square chain might naturally enter his mind. Well, that is just one square rod; four rods make one chain; therefore, sixteen square rods make one square chain. There would be a certain convenience about that which we do not get in using for a ratio in superficial measure a number which is not a perfect square; as when we go on to say that ten square chains make an acre. How long is one side of a square acre? Nobody remembers the length either in chains or any other measure. This affords comparatively little reason, however, for having a square at the foundation of our arithmetic; for it is not necessary to have the sub-units in superficial measure connected by such small gradations as the ratios of eight, ten, or twelve; it is sufficient to

use the squares of those numbers. We have been getting along in the past without any intermediate unit of area between the square inch and the square foot, which is 144 square inches, or between the acre and the square mile, which is 640 acres.

I consider sixteen to be out of the question as a base for arithmetic. It would require about three times as much multiplication table as ten, and nearly twice as much as twelve.

The number eight, finally, has an advantage not possessed by any other proposed base; namely, it is a perfect cube. The value of this relates to cubical measurement and weight or other properties dependent thereon. We may illustrate again by referring to the British Imperial measures of capacity. There are eight pints in a gallon, and eight gallons in a bushel; consequently, if you have a pint measure, a gallon measure, and a bushel measure all of the same shape, all cubical, for instance, or all hemispherical, the sides or other homologous lines are in the ratio of one to two; each dimension of the gallon is half as large as the corresponding one of the bushel, and each dimension of the pint is half as large as the corresponding dimension of the gallon. If weights were in the same ratio we might have a similar relation there. The imperial gallon holds ten pounds of water. Suppose we had a ten pound brass weight, and geometrically similar weights equivalent to the pint of water and the bushel of water, of course one would be half as large in each dimension, and the other twice as large in each dimension as the ten pound or gallon weight. With any number which is not a cube a little awkwardness appears. Thus, a cord of wood is 128 cubic feet; what, then, is the length of a cubical wood-pile containing one cord? Evidently a number of linear feet expressed by the third root of 128, equal to  $5\frac{1}{4}$  an interminable decimal. I fail to see, however, that this is a matter of much consequence. It is very easy to imagine that a cord is of different shape from a cube. If we wish to call up a distinct picture to our minds by way of comparison, we can think of it as 8 feet long, 4 feet wide and 4 feet high. So if we had one weight or one capacity measure one twelfth as large as

another, we could make it half as long, half as wide, and one third as deep. Moreover we do not compare weights by measuring them, but we put them in the balance; and capacity measures are tested by the weight of water which they hold, in preference to any measurement. The present tendency is to sell goods by weight rather than by measure, when practicable, for the sake of fairness and accuracy. The grain business furnishes a good illustration of this; in it the bushel, originally a measure of capacity, is now defined to mean a weight.

The adoption of an octonary arithmetic was warmly advocated by Alfred B. Taylor, of Philadelphia, in his report, as a committee on weights and measures, presented to the American Pharmaceutical Association in 1859. Though I am unable to agree with his conclusions, I desire to express my admiration for his thorough discussion of the subject, and to acknowledge my indebtedness to him and to the authorities whom he cites for a large portion of the material of this paper.

## THE DENSITY OF SATURATED STEAM.

By JOHN W. HILL, M. E.

Written for VAN NOSTRAND'S MAGAZINE.

THE density of steam, as the term is commonly used by engineers, is the weight of a unit of volume, as compared with that of water at maximum density; and the specific or relative volume, is the measure of expansion of a unit of water, converted into saturated steam: The density and specific volume are reciprocal quantities, thus

$$D = \frac{1}{V}$$

when V represents the ratio of expansion of a unit of water, converted into saturated steam at pressure P.

Saturated steam, as the writer apprehends the term, is in itself an indefinite expression, from the fact that it has been variously used to denote different conditions of steam; as used in this paper it indicates heat saturation—that is, steam charged with the latent heat due the temperature and pressure of evaporation; any addition of heat elevating the temperature and superheating the steam, and any reduction of heat converting a portion of the steam into liquid water. Thus saturated steam cannot receive additional heat without becoming gaseous, and cannot part with heat without condensation, pressure and volume unchanged. The density of liquid water at different temperatures, and the law of dilatation, by changes of temperature, has been determined with great exact-

ness by various experimenters. Likewise the laws of expansion of gases according to Mariotte and Gay Lussac, modified by the later experiments of Regnault, can be accepted with perfect confidence. When it becomes necessary, however, to resolve a given volume of steam into its constituent liquid water, at any temperature, the reduction is by no means an easy one: from the fact that experimental data is wanting, at present, to determine the specific volume, or density of saturated steam at various temperatures of evaporation.

Many difficulties beset the experimental determination of this problem, one of which is that suggested by Mr. Charles F. Porter in his treatise on the steam engine indicator, that, "the expansion and contraction of volume consequent on changes of pressure, and those consequent on the changes of temperature cannot be investigated separately." The truth of this is obvious, for with a reduction of volume of a given quantity of steam, there is an increase of pressure and density, due to forcing the molecules of the mass into closer contact, at the same time the work expended in overcoming the resistance of the mass to reduction of volume is reproduced in the steam by an elevation of temperature, if the previous volume were saturated steam, or by an evaporation of the liquid water, if the previous volume was inferior to saturated

steam. If the initial quantity were saturated steam, the heat due to the work expended in reducing the volume, would appear as a super-heat, and the dilatation due the super-heat, could be determined by Gay Lussac's law; conversely if the initial quantity were inferior to saturated steam, the heat due to the work expended in the reduction of volume, would appear as latent heat in the atoms of liquid water unevaporated in the steam. In the first instance, we would have an increase of pressure and temperature, and in the second instance, an increase of pressure and density, due to distinct and separate causes, and, as Mr. Porter asserts, the investigation of each cause cannot be conducted independently.

According to Rankine the dilatation of a perfect gas is represented by the following law

$$\frac{P.V}{P'.V'} = \frac{461.2 + t}{461.2 + t'}$$

Thus if the absolute temperature be doubled, the volume under constant pressure will be doubled, or the pressure under constant volume will be doubled. But Regnault's experiments have shown the coefficient of dilatation to be greater under constant pressure than with constant volume.

This law in a modified form has been used to calculate the relative volume of steam. When Regnault was commissioned to investigate the laws and phenomena of steam, as affecting its useful application, the density formed no mean element of the work. But while his experiments have determined with great precision the relations of temperature, and pressure, of saturated steam; together with the specific heat under constant pressure and constant volume, and the thermal value of a unit of steam (by weight) at different temperatures of evaporation; his investigations it seems never extended to a determination of the density.

Rankine has computed the density of steam from its chemical composition, upon the assumption that saturated steam is a perfect gas: thus two volumes of hydrogen, combine with one volume of oxygen, forming two volumes of vapor of water, having a density of .622 as compared with air.

The weight of a cubic foot of dry air at 32° Fahr., and, under pressure of one atmosphere, is usually taken at .080728 pounds: hence weight of cubic foot of vapor of water at same temperature and pressure;

$$D = .080728 \times .622 = .050213 \text{ pounds.}$$

As suggested by the author, this quantity (.050213), is to be used in calculation only, since saturated steam cannot exist under the assumed conditions: [the temperature of evaporation under pressure of 14.696 pounds (one atmosphere) being 212° Fahr., and, the pressure of evaporation at 32° being .089 pounds.]

If the gaseous theory of steam were correct, then the density under known conditions of pressure and volume could be determined by the Mariotte law. But the density of steam, under specific conditions, is known to be greater than the density assigned by theory, and such limited experiments as have been made in this direction, which while they do not establish other than empirical formulæ, they have determined beyond a doubt, that the laws governing the density of perfect gases, will not apply to saturated steam.

Regnault observes that, "mechanicians admit for the most part that the weight of a cubic meter of vapor, of given pressure and temperature, may be calculated by applying to it the law of Mariotte, and the law of uniform dilatation of gases. But these laws are not rigorously exact even for permanent gases, and it is to be feared they may be completely false for saturated vapors."

Rankine has also computed the density of saturated steam from the latent heat, and suggests that "the density of the vapor of water as computed from its latent heat of evaporation, is greater than that corresponding to the perfectly gaseous state;" again, "for steam at low pressure the difference is trifling but increases rapidly as the pressure increases." Fairbairn has made the density of saturated steam the subject of direct experiment upon which the well known Fairbairn and Tate formula is based. The principle upon which the experiments were conducted is described as follows:

"The density of steam is ascertained

by placing in a glass globe of measured capacity, and exhausted of its air a weighed quantity of water."

"The globe is then placed in a bath and raised in temperature until the entire weighed portion of water is converted into steam; the temperature at which this happens is noted and we have thus the three elements for calculating the density, the temperature, the volume, and the weight from experimental data."

The apparatus employed by Fairbairn was extremely delicate, and were it not that certain doubtful elements unnoted at the time of the investigations entered into the subject, it is possible that these experiments, while not conclusive in themselves, would have formed a basis for more extended and determinate investigations into the density of saturated steam.

The first objection to a law based on Mr. Fairbairn's experimental results is the assumption, that the steam in the measured glass globe was saturated steam at the time test observations were made. No attempt was made (at least none was recorded) during the experiments to determine whether the steam was saturated; and the conditions under which evaporation occurred were such as to leave room for grave doubts as to the precise condition of the steam, at time test observations were made. It is well known that steam is capable of holding in mechanical suspension a large percentage (by weight) of water unevaporated, and at the same time, as observed through a glass boiler, appear transparent. From experiments by the writer upon steam in a clear flint glass boiler, it appears that a primage of 20 per cent. by weight, can exist and not affect the transparency or ethereal appearance of the steam. At the present time it is the practice with engineers in charge of nice experiments to provide especial apparatus to determine the percentage of liquid water contained in the steam, and any economy test of engine or boiler, or capacity test of boiler, is worthless unless this data is obtained. Upon the other hand, steam may be at superheat, and, it is equally important that this fact be known and its value determined, in such tests as are to be of permanent value.

Fairbairn's apparatus was such as to

preclude the possibility of superheat in the test quantity of steam. And (in the writer's opinion), as he conducted his experiments it would have been impossible to produce saturated steam. If this be true then any law based on these experiments is not a law in fact, and the Fairbairn and Tate formula can be reliable only under conditions similar to those existing during the experiments. And as no record was made of the quantity of the steam experimented on it is a very uncertain question as to where this formula will apply.

The second objection to the Fairbairn methods for determining the density of steam, is in the use of glass globes. It is well known to those who have had occasion to use glass boilers for experimental purposes, that the application of heat alone will be insufficient to convert all the contained water into steam, the attraction between the glass and the water being sufficient to retain in contact with the glass, a portion of the water unevaporated. Rankine observes that "if in experiments on the density and expansion of steam glass vessels are used, a new cause of uncertainty is introduced, by the fact that the attraction is sufficient to retain in the liquid state, and in contact with the glass, a film of water at a temperature at which but for the attraction of the glass it would be in the state of steam."

The formula deduced by Mr. Tate from Fairbairn's experiments is

$$V = 25.62 + \frac{49513}{1 + .72}$$

where  $V$  represents the ratio of expansion of a unit of water, converted into saturated steam, at  $I$  inches of mercury.

From the experiments of Arago and Dulong, Pambour has deduced the following formula

$$V = 37.3 \frac{458 + t}{p}$$

where  $t$  represents temperature of evaporation corresponding to  $p$  pounds (absolute) pressure. This is a popular formula for computing the relative volume of saturated steam, and will be found in many standard text-books. Haswell uses it in his manual for engineers, but substitutes 76.5 as the multi-

plier in the second member of the equation, and  $p$  is taken in inches of mercury.

This author also offers a formula for the determination of the relative volume of steam based on Gay Lussac's law, but as this law relates to perfect gases, and as steam is not a perfect gas at saturation, it is not clear how it can be made to solve the problem of relative volume. The dilatation of steam above saturation or superheated steam can be determined by Gay Lussac's law; but the ratio of expansion of a unit of water, converted into saturated steam, appears to the writer to be beyond the reach of this law.

According to Weisbach (Vol. 1, Art. 392), "Gay Lussac's experiments repeated more recently by Rudberg, Magnus and Regnault, have shown that for the same density the tension, and for the same tension the volume, of one and the same quantity of air increases with the temperature." Upon the assumption, however, that "for the same tension and temperature, the density of steam is about  $\frac{5}{8}$  of that of atmospheric air. Weisbach proposes the following formula for the density of steam

$$D = \frac{.050475}{1 + .00204 (T - 32)}$$

$$\frac{P}{14.7} = \frac{.003434 P}{1 + .00204 (T - 32)}$$

where  $D$  equals the weight per cubic foot of steam, at pressure  $P$ . The objection to this formula, is that the density of steam does not obey the gaseous laws; and Fairbairn's experiments, which while they do not establish a precise law for the density of saturated steam, do show in the language of the experimenter, that "the density is greater than that given by the gaseous laws, even at low temperatures."

Computing the density of steam by Rankine's formula, based on the latent heat, proves that the density is greater than that assigned by the gaseous laws.

The necessity for further experiments, and the construction of formulæ that will relieve this problem of some of the uncertainty that now surrounds it, is desired by all having occasion to deal with the question of density. And no doubt it will be determined at a future period, very much as Regnault has determined the relations of temperature and pressure and specified heat by steam.

## MODERN BLASTING EXPLOSIVES.

From the "London Mining Journal."

At no period in the history of the civilized world has the adage "Time is money" been more forcibly illustrated than in the actual demand by the mining community for the strongest explosives—or, in other words, for the explosive which will produce the greatest effect with the smallest labor or time employed in boring holes to receive the same, or in tamping. Again, the military engineer keeps himself *au fait* of all new destructive agents which, under the smallest weight, will do the most mischief, the most essential point in using explosives in the field being to place the charge on the proper spot at the proper time, which means quick carriage and hence small weight. Chemistry and engineering have not been slow to respond to the demand, and amongst the host of explosives

which have been brought forward at different times there are some two or three which have attained a decided pre-eminence, each in its way. We refer to dynamite, tonite, and compressed gun-cotton.

The literature of modern explosives exists only in the shape of papers read at institutions, and pamphlets from scientific specialists. We will endeavor in the following lines to gather a few notes which we believe may be of some value both to the scientific and the practical man. It is not our intention to dwell at length on what may be called the earlier history of the explosives under consideration. We will only call to mind the points of interest which have marked their progress towards practical utility. It is well known that guncotton

was first introduced to the public by Schonbein in 1846. Great things were expected from the discovery, and yet in a few years, after a brief but eventful career, guncotton was relegated to the laboratory shelf, and amongst the sufficient causes for such a proceeding we may mention the inability of the makers to produce a stable article, and also the enormous bulk occupied by a charge of the explosive, as well as its inherent property of disengaging upon explosion a large amount of carbonic oxide gas, which, in close workings, is not only objectionable on account of health, but absolutely dangerous as fire damp. Ways and means as ingenious as numerous were tried in divers countries to master this promising but crude invention, but the only improvement, partially successful was for a long time obtained in nitrating the guncotton with saltpetre. This material reduced the carbonic oxide and added considerably to the strength of the guncotton, but the fumes resulting must have been very inconvenient, as the carbonate of potassa produced very readily remains in suspension in the atmosphere for a long time, not to mention the almost inevitable presence of cyanide of potassium, but the most potent objection to its use was its liability to explode spontaneously.

Things were in this condition, and ordinary gunpowder continued to reign supreme, when Sobrero somewhat before 1860 introduced his nitroglycerine. New hopes were raised, and as a consequence money, labor, and ingenuity were devoted to the work, but nitroglycerine, like guncotton and, indeed, all great inventions, had a hard fight before it could inspire confidence in the public, for the material as then made was very unstable, and even when pure—chemically stable, if we may use that expression—it was liable to disruption from physical causes. One of these, still unexplained, happens during the passage of the frozen nitroglycerine from the solid to the liquid state, as if the crystals were suddenly broken by a too sudden application of heat, as in the well-known decrepitation of common salt; a similar theory has been used to explain explosions which sometimes occur with fulminate of mercury when this substance is put to dry, which, although quite pure, may explode

at a temperature far below its normal exploding point.

Now we come to one of the important epochs of invention—the discovery of dynamite by Mr. Alfred Nobel. Dynamite is nitroglycerine mixed with an earthy absorbent, the result being a plastic instead of a liquid substance, and therefore more manageable, the tendency of the nitroglycerine to spontaneous explosion in thawing being considerably reduced by reason of the modification in the structure of the compound. The nitroglycerine used in the manufacture of dynamite can now be made quite pure, so the enormous consumption of the produce is justified in the absence of any competing explosive. Let us hope that Mr. Noble will by his intended new admixture entirely destroy the causes which bring about the terrible calamities frequently reported in the papers, such as that at Parma, and at Bangor quite recently, where dynamite exploded while being thawed. During the period of the progressive success of nitroglycerine and dynamite, guncotton had a hard struggle for existence, the best, if not almost the only, friend of the latter substance being Professor Abel, F.R.S., who with a clear practical mind, recognizing that no inherent property of guncotton stood in the way of its practical employment, set himself to solve the problem of its utilization. First he cut the guncotton fiber into pulp, thereby reducing its bulk and improving the stability of the guncotton by permitting a more thorough washing. It was then found that the power of exploding by a flame was very much reduced, in consequence of the closer texture of the compressed dry pulp, but as Mr. Nobel had successfully applied the detonator to his dynamite, so did Mr. Brown, of Woolwich, succeed in producing a first-class explosion with guncotton thus detonated.

These are splendid achievements, and the next step—nitrated pulped guncotton—was actually making its appearance when occurred the Stowmarket calamity, which drove all confidence away for a time. It was then proposed to use the pulped and compressed guncotton in the wet state, as it was found that it could be exploded in this condition by using a strong primer of dry guncotton; indeed, large quantities are now being employed

under this condition, but of course all thoughts of using a nitrate with it was abandoned, as saltpetre does not answer in conjunction with wet guncotton. This was very regrettable, as it is well known that by nitrating guncotton its strength, as measured by the best energy it can produce, is increased fully thirty per cent., and moreover, no carbonic oxide is produced—a very important item in ill-ventilated workings. Unnitrated and wet compressed guncotton is mainly used for military and naval purposes, on account of its safety over dynamite and its remaining unaltered by climatic changes; at all events it is relatively easier to keep it from freezing. Miners, however, who buy explosives for profitable purposes, will not use it in any quantity. There remained, therefore, ample room for further progress in dry nitrated guncotton compressed to the smallest bulk. This has been obtained in an explosive called tonite, manufactured by the Cotton Powder Company of Faversham. The remarkable results obtained by the officials of that company in producing this explosive renders unnecessary any apology on our part for explaining at some length what these results are, and how much the mining community, and, indeed, the nation, may be benefited by their labors. About 1873 the Cotton Powder Company, under a somewhat different name, commenced operations, their object being, amongst other things, to produce nitrated guncotton according to the terms of their license, and, commencing so soon after the great catastrophe at Stowmarket, it required no small amount of courage to attempt the manufacture of apparently a similar explosive, although it offered a most promising reward to success.

Tonite or cotton powder is now well known to all mining engineers under the shape of a dense dry cartridge; it is generally waterproofed, and is not altered by any conditions of temperature. The density of tonite is about 1.50—that is, it goes into the same space as dynamite, and in about two-thirds that of compressed guncotton. The base of tonite being guncotton the first care of the manufacturers was to devise practical means of purifying that substance, which being produced of ordinary cotton steeped in mixed sulphuric and nitric

acids contains in its crude state some portion of that mixture, with other nitro compounds. The free acids are easily eliminated by washing with water, with or without alkaline addition, but the nitro compound impurities—nitro-starch, nitroglycerine, and other products of the resins, sugar, and impurities of the original cotton—are not so easily got rid of, being insoluble, and partly imprisoned in the capillaries of the cotton fibre. It had been long known to the chemical student that inferior nitro compounds are partly destroyed in boiling water, and that ammonia is a very powerful reducing agent of these compounds. It only needed practical hands to unite the processes. As the washing plant now stands at Faversham any quality of guncotton can be purified as to its dangerous impurities in about two hours, and the same process applies whether the fibre is very long or very short. This process has been in operation for about five years with perfect success, and we understand that it is partly followed at the Government works at Waltham Abbey. It can at all events be assumed that Prof. Abel has satisfied his mind about the value of such washing or boiling process, for it will be remembered that at the last meeting of the British Association, at Portsmouth, he said that guncotton could now be made quite reliable.

From pure guncotton to dry nitrated powder there is only one step—choose the proper nitrate. Before settling this point we may dismiss chlorate of potash, the most powerful of all available oxidizing agents. It is known that guncotton used with the proper quantity of chlorate of potash is superior as a blasting agent to the best nitroglycerine, but, like this substance, it is liable to explode under the slightest rough usage. The available nitrates for mixing with guncotton are the nitrates of ammonia, potassa, soda, baryta, strontia, &c. The nitrates of ammonia, soda, and to a certain extent strontia, are deliquescent, and have never been used with any success for a length of time; all these nitrates except that of baryta are very soluble, and thereby interfere with the manufacture, and, moreover, give very disagreeable fumes in the mines. In short, after many trials nitrate of baryta was definitely chosen. *Prima facie* it

is the best suited to the purpose, as containing more earthy base in a given weight, but if we bear in mind that in mining the space occupied by the explosive is more an object than its actual weight, and as it is possible by the use of nitrate of baryta to lock up under the very smallest possible space a larger amount of energy than by the employment of any other nitrate, the choice then appears justified. There is another point to be considered in favor of tonite—its economy of manufacture. Tonite can be made at forty to fifty per cent. less cost than guncotton, and of thirty per cent. greater strength. In these times of heavy military and naval expenditure it might be well worth considering what would be the economy to the nation in substituting tonite for ordinary wet guncotton, considering that the former is quite as safe, if not safer, than the latter, for wet guncotton stored in South America has lately given cause

for serious doubts as to its stability. We have said enough for the present to show that the question of a blasting agent is being vigorously studied, and that progress has been made; there are, however, a great many other very important points which will suggest themselves to the consumer, such as those under the head of plastic explosives *v.* solid cartridges, &c. These have been well tested, every experiment conforming with those thermodynamic theories, which teach us that heat alone is force irrespective of space, and as the miner's chief object is to economise space, to minimise his boring, and the issue as between solid tonite and plastic dynamite is only about five per cent. of space, when all the pleas are considered, the question may be pronounced practically settled against dynamite in favor of its younger cousin tonite, against the daughter of nitroglycerine in favor of the offspring of guncotton.

## REMARK ON PROPOSITION IV OF "NEW CONSTRUCTIONS IN GRAPHICAL STATICS."

By WM. CAIN, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

PROF. EDDY'S note on this proposition in the May number of this Magazine suggests the following confirmation of this fundamental law.

Wm. Bell has shown (see "Stresses of Rigid Arches, &c.," Van Nostrand's Magazine Vol. 8, p. 199) that "the *neutral line* of the arch rib, having been divided into equal lengths," the conditions that an arch rib be "fixed at the ends" are,

$$\sum M = 0, \sum My = 0;$$

and he should have added his eq. (5) when  $v = 0$   $\therefore \sum Mx = 0$ .

For very flat arches, the *span* may be divided into equal parts to give a near approximation which plan was adopted by Prof. Eddy, (see April No., 1878).

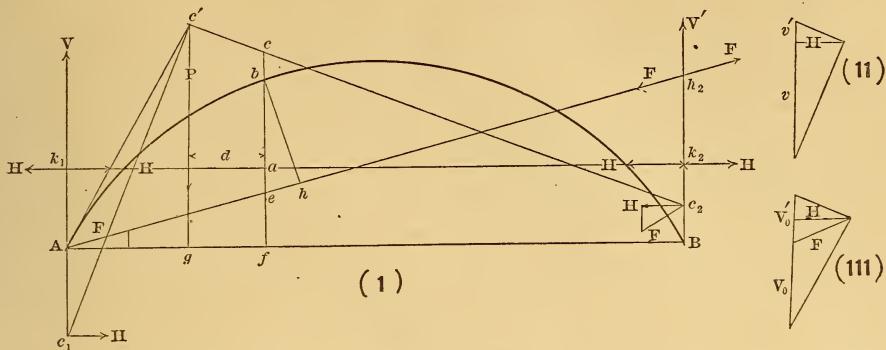
First consider the arch *ADB* as "fixed" at the abutments *A* and *B*. The resultant of the vertical reaction *V* and horizontal force *H* cannot pass through *A*, as there would then be no moment

there to cause fixity, but through some point *c*. Similarly the resultant of *V* and *H* at right abutment passes through *c*. Now we do not disturb the equilibrium by applying at *k*<sub>1</sub> and *k*<sub>2</sub>,  $+H$  and  $-H$  acting horizontally in line *k*<sub>1</sub>*k*<sub>2</sub>, but we thereby transfer *H* at *c*<sub>1</sub> and *c*<sub>2</sub> to *k*<sub>1</sub> and *k*<sub>2</sub> and add the moments  $H.k_1.c_1$ ,  $H.k_2.c_2$  at *A* and *B* respectively; so that the moment about a point *b*, *d* to right of weight *P*, *x* to right of *k*<sub>1</sub> and *y* vertically above *k*<sub>1</sub> is,

$$M = (Vx - H.k_1.c_1 - Pd) - Hy. \quad (1)$$

The term,  $Pd = 0$ , for points to left of *P*.

The term  $(Vx - H.k_1.c_1 - Pd)$  is the moment at *b* of the rib acting as a continuous girder with end moments at *A* and *B*;  $H.k_1.c_1$  and  $H.k_2.c_2$  respectively. In fact, if there were no moments at *A* and *B*, then *c*<sub>1</sub>*c*<sub>2</sub> with a closing line *c*<sub>1</sub>*c*<sub>2</sub> would be the equilibrium polygon. Assume  $H.k_1.c_1$  to be the moment re-



quired at  $A$  to "fix" the end of the rib acting as a girder, and write  $M_c = Vx - H.k_1c_1 - Pd$  = moment due to loads, &c., as for a girder; also write  $M_d = Hy$  = moment due to  $H$  acting at  $k_1$ .

$$\therefore M = M_c - M_d \quad (2)$$

Now  $k_1c_1cc_2k_2$  is the equilibrium polygon of the rib acting as a girder,  $k_1k_2$  being the "closing line," as will be proved: Now having assumed  $II.k_1c_1$  to produce bixity at  $A$ , the moment required at  $B$  to effect the same object at that point can have but one value found by taking moments about  $B$ . Now the supposed forces acting along the sides of the equilibrium polygon  $k_1c_1, c_1c, cc_2, k_2c_2$ , being balanced as seen by reference to force diagram, leaves

$V, P, V'$ , and couples  $H.k_1c_1$  and  $H.k_2c_2$  in equilibrium.

$\therefore$  Taking moments about  $c_2$ , we get

$$H.k_2c_2 = Vl - H.k_1c_1 - P.GB$$

the same value as we should find by the principle of moments. Hence  $k_1k_2$  is the true closing line for the arch rib acting as a girder fixed at the ends. It is also the closing line of the rib considered as an equilibrium polygon, whose moments  $M_d = Hy$  are entirely due to the horizontal thrust acting at  $k_1$ . So that if the equilibrium polygon due to the rib acting as a girder could be drawn with a pole distance  $H$  and with  $k_1k_2$  for its closing line, then from eq. (2) the ordinates intercepted between these last two polygons multiplied by  $H$  give the real bending moments acting on the arch.

We have previously seen that for a rib fixed at the ends we must have the conditions fulfilled.

$$\Sigma M = 0, \Sigma Mx = 0, \Sigma My = 0 \quad (3)$$

Now the rib acting as a girder fixed at the ends by the moments applied must satisfy the conditions.

$$\Sigma M_c = 0, \Sigma M_c x = 0, \Sigma M_c y = 0 \quad (4)$$

whence

$$\Sigma (M_c - M) = 0, \Sigma (M_c - M)x = 0$$

$$\Sigma (M_d - M)y = 0$$

whence by eq. (2) we have also,

$$\Sigma M_c = 0, \Sigma M_d x = 0, \Sigma M_d y = 0 \quad (5)$$

In words, these eqs. show that the closing line  $k_1k_2$  must be determined "from the same considerations respecting supports, etc.," for the curve  $c$  as the curve  $d$ . (Fig. 2 of "New Constructions, &c.")

Prof. Eddy has ably shown how, from these equations, the curve of moments  $M$  is finally drawn.

It may be remarked that the end moment  $H.k_1c_1$ , which was assumed, is readily determined by the conditions (4) of a girder fixed at the ends. The pole distance  $H$  is then found by the conditions (3), whence the value of  $c_1k_1$  follows, giving a starting point for the true equilibrium curve which is then drawn.

It is seen from the foregoing that we first have to prove that  $k_1c_1cc_2k_2$  is the equilibrium curve, to pole distance  $H$ , whose moments are  $M_c$ . Next that the arch regarded as an equilibrium curve to a closing line  $k_1k_2$  and pole distance  $H$  gives the moments,  $M_d = Hy$ ; whence from eq. 2,  $M = M_c - M_d = H \times$  difference of ordinates from  $k_1k_2$  to rib and equilibrium polygon  $c$ .

It is seen that because eqs. (3) and (4) are true, that (5) is always true; which thus imposes similar conditions for the closing line of polygons  $c$  and  $d$  to fulfill as enunciated in Prop. IV.

If the arch is not fixed at one or both ends; still, whichever of the conditions (3) hold, give corresponding conditions in (4) and (5).

When the arch rib has end joints, as there can be no moments there, the points  $k_1$  and  $c_1$  are found at  $A$ , and the points  $k_2$  and  $c_2$  at  $B$ ; when Prop. IV evidently holds.

If one end of the rib is fixed and the other jointed, we may prove in an elementary manner, that Prop. IV is applicable as follows:

Suppose the true equilibrium polygon  $Ac'_2 \dots$  drawn. Let the force  $\bar{F} = H \sec. h_2 AB$ ; and conceive applied at  $A$  and  $c_2$ , two vertical equal and opposed forces, whose value is the same as the vertical component of  $\bar{F}$ . This does not destroy equilibrium, but replaces  $V$  and  $H$  at  $A$  by  $V_0$  and  $\bar{F}$ , see Fig. 3; similarly  $H$  and  $V'$  at  $c_2$  are replaced by  $\bar{F}$  and  $V'_0$ , calling  $V$  and  $V'$  the real reactions at  $A$  and  $c_2$ .

Now if we apply at  $h_2$ ,  $+F$  and  $-F$ , as drawn, we do not affect equilibrium, but we thereby transfer  $F$  at  $c_2$  to  $h_2$  and add the couple, whose moment  $= F \times h_2 c_2 \cos. h_2 AB = H. h_2 c_2$ .

If we assume that this couple is of sufficient intensity to fix the end  $B$  of the rib acting as a girder then the equilibrium polygon for the girder is  $Ac'_2 h_2 A$ , as is evident by "following round" the force polygon (III): so that for a point  $c$ ,  $M_c = H.ec$ .

Let us take moments about the point  $b$

$$M = (V_0 x - Pd) - F.b\bar{h}$$

$$\therefore M = M_c - H.be = H.bc$$

as before found.

The assumed moment at  $B$  can be obtained as Prof. Eddy has shown from the second of conditions (3). A similar condition in (5) determines the closing line  $Ah_2$  for the curve of the arch considered as an equilibrium polygon with the same horizontal thrust  $H$ .

We have thus established Prop. IV for various styles of arch, it is believed, in an elementary manner.

It is stated by Prof. Eddy thus:

"Prop. IV.—If in any arch that equilibrium polygon (due to the weights) be constructed which has the same horizontal thrust as the arch actually exerts; and if its closing line be drawn from

consideration of the conditions imposed by the supports, etc.; and if furthermore, the curve of the arch itself be regarded as another equilibrium polygon due to some system of loading not given, and its closing line be also formed from the same considerations respecting supports, etc.; then when these two polygons are so placed that their closing lines coincide, and their areas partially cover each other, the ordinates intercepted between these two polygons are proportional to the real bending moments acting in the arch."

## REPORTS OF ENGINEERING SOCIETIES.

ENGINEERS' CLUB OF PHILADELPHIA. — A meeting of the Club, held April 20, the Secretary read a paper by Mr. Wm. F. Biddle, entitled "Notes on the Location and Construction of a Mining Water Works in Venezuela." The work described was that of locating and constructing a pipe line to take water from the Orinoco River, three miles inland and 285 feet high to a stamp mill at the outcrop of a rich quartz vein, the mill having been built there in the disappointed expectation of getting water by sinking a slope to a moderate depth on the vein. The paper was fully illustrated by profile and sketches showing how the work was done.

The line was laid with four-inch and five-inch cast iron pipes, and with wooden troughs seven inches wide by six inches deep, two Worthington duplex pumps were used to operate the line, one located at the river and the other 5,800 feet from it. The starting point in both the preliminary and final surveys was the second pump. In fact the whole plan grew out of the remarkable advantages afforded there for delivering the water on top of a high plateau through a comparatively short discharge pipe. The first pump discharged through a pipe 464 feet long, with a lift of 160 feet, into troughs which followed the contour of the hills, with a falling grade of  $\frac{3}{10}$  per 100 feet. Before reaching the second pump two ravines were crossed by means of inverted syphons. In calculating the heads for these the wide differences between the formulae of Weisbach, Etelwein and others became very apparent. The comparison of these formulae and notes on Kutter's formulae for open channels formed a very valuable and interesting feature of the paper.

Mr. John Bogart remarked that the paper was one of very great interest, and that it brought out some points upon which engineers are in great need of practical information. A paper by Gen. Theo. Ellis, which he had read at the New Orleans meeting of the American Society of Civil Engineers, showed the same unsatisfactory results in a comparison of formulae relating to the flow of water in small channels.

Mr. Henry C. Lewis made some remarks in regard to a deposit of coal in Montgomery County, to which he had referred at the meet-

ing of the Club held March 16th. Upon visiting the locality he had found it one of very great interest. The deposit of coal does not occur at the lower boundary but toward the center or upper center of the Mesozoic red sandstone. The sandstone has a flat dip S. W., and shows a low anticlinal fold.

Mr. Ingham remarked that there are several questions connected with the Mesozoic formation which are of very great importance, and which it is hoped will be solved by the present Geological Survey of the State. The formation is broken up by numerous trap dykes which are often accompanied by minerals of economic importance. In many places the sandstone has been forced up into dome-shaped folds, where the trap dyke has not reached the surface. Such was the case at the Sellersville Tunnel and was the cause of very great expense to the N. P. R. R.

Mr. Percival Roberts, Jr., called the attention of the Club to some notes on an "Empirical Formula for estimating the Strength of Wrought Iron Beams, Channels, &c."

Mr. Roberts thought the formula might be found convenient for making rough calculations on account of its simple form.

Considerable discussion followed in regard to the various reasons for variations in the strength of manufactured iron, methods of testing, &c.

Mr. Bogart called especial attention to the work of the U. S. Board for testing iron, steel and other metals. Congress has appropriated, and the Board has expended nearly one hundred thousand dollars. A clause in the Act creating the Board provides that it shall cease when the appropriation shall have been spent. The Board have gone through enormous preliminary labor and have cleared the ground for effective work. If Congress refuse now to continue the appropriation, and the Board is dissolved, the work already done will be measurably lost, and a new Board would have to go through much of the preliminary work again. In the meanwhile we will go on for years groping in the dark for the knowledge which the Testing Board is organized to procure—these years being marked, at short intervals, by disastrous blunders of engineers, architects, builders and mechanics. On the other hand, if the Board is sustained, the knowledge obtained will be conducive to the great material interests of our people, and it will enable us to design and execute works creditable to ourselves and to American engineering.

Upon motion of Mr. Ingham, a Committee was appointed to memorialize Congress, asking a continuation of the work of the U. S. Board for testing metals.

**IRON AND STEEL INSTITUTE — REPORT OF COUNCIL FOR THE YEAR ENDING DECEMBER 31, 1877.**—The Council, in presenting their Ninth Annual Report, have much pleasure in being able to congratulate the members on the continued prosperity of the Institute.

The total number of members exceeds nine hundred. There continues to be a steady accession of new members, contributed both by this and foreign countries, forty-seven being

proposed for election at this meeting. The Council refer with much gratification to the increase of foreign members, showing, as it does, that the objects and the proceedings of the Institute are fully appreciated by Continental and American metallurgists.

At the two general meetings, held during 1877 in London and Newcastle, papers were read which in the opinion of the Council were well calculated to promote the objects and maintain the prestige of the Institute. The subjects considered at these meetings were:

Paper by Mons. F. Gautier, Paris. On Solid Steel Castings (*Acier sans souffres*).

Two papers by Mr. I. L. Bell, M.P., F.R.S. On the Separation of Carbon, Silicon, Sulphur and Phosphorus in the Refining and Puddling Furnace, and in the Bessemer Converter.

Paper by Mr. E. Riley, F.C.S. On the Estimation of Manganese and Iron in Iron Ores and *Spiegeleisen*.

Paper by Mr. E. Riley, F.C.S. On Chromium Pig Iron made by the Tasmanian Iron Co.

Paper by Mr. H. Henry Simon. On Chaudron's method of Shaft-sinking through Water-bearing Upper Strata.

Paper by Dr. C. W. Siemens, F.R.S. On some further results obtained by the Direct Process of Manufacturing Iron and Steel.

Paper by Mr. R. Howson. On Mechanical Puddling.

Paper by Mr. A. L. Steavenson. On the Manufacture of Coke in relation to the Iron Trade of the North of England.

Paper by Mr. G. C. Greenwell. On the Geological Features of the Great Northern Coal Field.

Paper by Mr. Chas. Wood. On Four Years' Improvements in the Utilization of Slag.

Paper by Mr. A. Thomas. On the latest Improvements in Belgian Merchant Rolls.

Paper by M. Gautier, C.E. On results of Experiments with Cannon Manufactured from Steel without Blows.

Papers by Dr. Percy, F.R.S. On the Protection from Atmospheric Action which is imparted to Metals by a Coating of certain of their own Oxides respectively; and on the cause of Blisters on Blister Steel.

The success of the meeting held at Newcastle in September amply justified the selection of that place by the Council, whose best thanks are hereby conveyed to the Local Reception Committee, to the Local Hon. Secretaries, to the Owners of Works in the locality, to the North-Eastern Railway Co., to the Cleveland Ironmasters, and to all others who helped to make the occasion agreeable. The attendance of members at Newcastle was larger than at any previous meeting of the Institute, and the large number of visitors who sought admission proved the interest taken in the proceedings.

The receipt of an invitation from M. Tresca, on behalf of the *Société des Ingenieurs Civils*, to visit Paris in the ensuing summer, and the concurrent holding of the International Exhibition in that city, have induced the Council to recommend that the next autumnal meeting should be held in Paris.

## IRON AND STEEL NOTES.

**THE MANUFACTURE OF IRON AND STEEL.**—No man better deserves the warmest thanks of our ironmasters than Mr. I. Lothian Bell, seeing that for years past he has devoted a great deal of time to finding out the best means of producing pig with the smallest consumption of fuel. In conjunction with other North Country makers, he has succeeded, for he tells us that where not so long since 70 cwt. of coal were required to make 1 ton of pig, the same is now accomplished with from 41 to 45 cwt. That is with respect to the Middlesborough ironstone, which is by no means rich, giving only about 30 per cent. of metallic iron, whilst for Spanish, and other ores yielding 50 per cent. of iron and upwards, the quantity of coal for smelting would be probably 5 cwt. per ton of pig less. This great economy in fuel in the manufacture of iron has been of the greatest benefit to the country, as it has enabled us to supply even continental makers with pig at a less price than they could produce it. But Mr. Bell has gone further, and in another direction has endeavoured to produce iron from Cleveland stone so clear of phosphorus that it can be readily converted into Bessemer. This is the great difficulty to be overcome in the conversion of such ores into steel fit for rolling, and Mr. Bell appears to have gone into it most thoroughly, and if the results are not all that could be desired, he is certainly on the high road to success. For the purpose of freeing the pig from its impurity, Mr. Bell washes out the phosphorus by means of oxide of iron, and the question naturally enough arose as to whether or not the process would be too costly to pay. It appears that about 10 cwt. of oxide of iron is used with every ton of pig, and if that would cost 10s. then it was considered that it would scarcely pay. But it is quite probable that a much less quantity of oxide of iron may be found in future manipulation to attain the desired results. One of the most important points to be realized is as to the quantity of phosphorus that could be left in a steel rail without injuring it in any way, for as we all know that it is the great enemy of both the Bessemer and open-hearth manufacturers, yet for some purposes even in steel it may be a valuable ingredient. Formerly spiegeleisen was used to decarbonize Bessemer steel to impart manganese to the oxygen of the oxide of iron formed in the Bessemer process, but now it is adopted not only to remove the oxygen, but to mix the manganese with the steel; and it has been asserted by a high authority that if the proportions of silicon and phosphorus were sufficiently low, and the carbon did not exceed a third of 1 per cent., manganese to the amount of three-quarters of 1 per cent. would give the resulting product a high degree of toughness and hardness combined—a degree of suitability for rails which no proportion of either carbon or manganese not associated could impart. But we are told that in the Great Northern Bessemer rails as much as 0.274 per cent. of phosphorus has been found, but the question really appears to be as to what amount of phosphorus a rail would stand without impair-

ing it in any way. This satisfactorily determined, the experiments would be resumed by Mr. Bell with greater certainty of succeeding. He would also be able to define accurately the different proportions of the various ingredients that are necessary for bringing out a certain quality of steel, which can scarcely be said to be the case at present, although we are frequently told as to the elasticity and resistance of steel by testing.

But that steel is about to undergo another revolution is pretty evident, for at the recent meeting of the Iron and Steel Institute, on the discussion of Mr. Bell's paper, Mr. Snelus said that six years ago he took out a patent for converting Cleveland pig into steel, and in reducing the phosphorus in it to under 0.1 per cent., using limestone for the lining of his furnace. He said he had such confidence in his patent that he intended renewing it, although it was six years old. This process no doubt would be less expensive than that of the oxide of iron, but there appears to be some difficulty in the carrying out of the process with respect to the furnace; but, if all other details can be successfully carried out, no question but what that will be easily overcome. But a still greater surprise was in store for the members of the Institute by Mr. Sidney Thomas declaring that he had succeeded in entirely removing phosphorus by the Bessemer converter. This was certainly a startling announcement to make, and equally so was the statement that he had the results in his pocket of more than 100 analyses of different experiments for the very small quantity of 6 pounds up to 10 cwt., and all the results carried out the theory with which he originally started. In the worst results 20 per cent. of phosphorus was removed, and in the best 99.9. This latter result one would think would be sufficient for anything, and we feel sure the particulars will be looked forward to with much interest by our ironmasters and Bessemer makers. We have, however, three distinct processes before us by which the phosphorus can be eliminated from Cleveland iron, and the latter converted into Bessemer steel. As to the comparative merits of each process there is not sufficient data before us to give an opinion, seeing that each proposal may be said as yet to be in only an embryo state. But before long it is to be hoped detailed results of further results will be given, when the public will be in a position to judge of their respective merits. In the meantime we understand Mr. Bell will proceed with his experiments, and without ignoring the claims of others in the same field to every consideration, we believe we only echo the feeling of all persons connected with the iron and steel trades in wishing him every success.

## RAILWAY NOTES.

**EXPERIMENTS ON STEEL RAILS**—By J. VAN HAMEL.—These experiments were made on steel rails ordered for the Transvaal Republic, and manufactured at John Cockerill & Co., of Seraing. They were of the Vignoles type, weighing 56 lbs. per yard, and of the following

dimensions: Height, 3.9 inches; breadth of foot, 3.9 inches; breadth of head, 2.2 inches; thickness of web, 0.4 inch. Sixteen rails were experimented on, and the tests and the results were as follows:

(A) The rail was to be placed on bearings 3 feet 7 inches, and receive a blow from a weight of 1,103 lbs., falling freely from a height of 19 feet 6 inches, without showing a set of more than 1.8 inch; and was then to be turned over and straightened back again under similar blows without breaking. The whole of the rails bore this test well, the largest set under the first blow being 2.1 inches. They were subsequently nicked in the foot, and then broken by blows of the same weight; the number of blows required varied from one to eight, the last number occurring with a rail which had been a long time under a hot sun, and may thus have been rendered more ductile.

(B) The rail, placed on the same bearings, was to support a weight of 9.8 tons at the center for five minutes without showing any permanent set; and subsequently a weight of 27.5 tons under the same conditions without breaking. The whole of the rails bore both these tests satisfactorily, the permanent sets in the second case varying from 1.97 to 4.9 inches.

(C) From each charge two small ingots were taken, and forged into bars 0.8 inch square, which when cold were bent double without breaking; the object of this test being to show that phosphorus, sulphur and silica were not present in an inordinate degree.

(D) Four pieces were cut off finished rails, forged into square bars, and then turned down to four different diameters, 0.59, 0.63, 0.61 and 0.73 inch respectively. These specimens, each 4 inches long, were then tested separately in a hydraulic press for tensional strength. The three first specimens behaved nearly alike, beginning to stretch sensibly at about 23.2 tons per square inch, and breaking at about 38 tons to the square inch, with a final extension of about 18.5 per cent., and contraction at the point of fracture of about 16 per cent. The fourth specimen began to lengthen at about 19 tons, and broke at 34.3 tons; but from the fracture it appeared to have been somewhat overheated, and thus not to give a fair test.

The above results show sufficiently the nature of the steel, which belonged to the category called in Belgium "Tres-tendre," or "Tendre," not capable of hardening in water. These qualities have from 0.18 to 0.20, and from 0.20 to 0.28 percentage of carbon respectively, and were used in this case on account of local circumstances, which did not allow of the quality "demi-dur," which is preferred in Europe. This quality has 0.28 to 0.30 percentage of carbon. The charge of raw material used by Messrs. Cockerill when making this steel is given in detail, and also its chemical composition when melted.

## ENGINEERING STRUCTURES.

THE EMBANKMENT OF THE THAMES.—At the meeting of the Institution of Civil Engi-

neers held on the 9th of April, the paper was on "The Embankment of the River Thames," by Mr. Edward Bazalgette, Assoc. Inst., C.E.

The River Thames was the arterial drain for 5264 square miles. Its source in Gloucestershire was 330 feet above the main level of the sea. It traversed 210 miles, and was tidal to Teddington Lock. In dry weather the discharge was about 470 million gallons daily. Its waters had been prevented from overflowing large tracts of land by embankments formed under various Acts of Parliament. The removal of Old London, Westminster, and Blackfriars Bridges, had enabled the tide to ebb and flow more freely by which the navigable channel had been deepened. The width of the river was, however, still very variable. Above Southwark Bridge it was 670 feet wide, and the waterway between the piers of that bridge was only 600 feet. At Hungerford Bridge, before the formation of the Victoria Embankment, the width was 1340 feet, whilst opposite Millbank it was only 610 feet, increased to nearly double that width at Battersea. Mud banks had formed along the foreshore, and between Westminster and Blackfriars about 27 acres of mud were exposed at low water on the north side.

The first commissioners for embanking the Thames were appointed in 1367. Acts for constructing embankments and improving the navigation were passed in the reigns of Henry VIII. and of Elizabeth. Sir Christopher Wren proposed an embankment from the Temple to the Tower after the fire of London in 1666. Sir Frederick Trench and Mr. Martin suggested similar embankments. In 1840 Mr. James Walker laid down a line for a northern embankment for the Corporation of London, to be raised 4 feet above Trinity high water. His line and levels had since been adopted. Various Parliamentary commissions and committees had considered the subject. In 1862, an Act was obtained by the Metropolitan Board of Works for the formation of the Victoria Embankment, from Westminster to Blackfriars Bridge. In 1863, another Act was passed for the construction of the Albert Embankment from Westminster to Vauxhall Bridge. And, lastly, in 1868 the Act for the Chelsea Embankment, from Chelsea Hospital to Battersea Bridge, was sanctioned. These embankments comprised about  $3\frac{1}{2}$  miles of river wall, and had reclaimed 52 acres of land.

The length of the Victoria Embankment was about  $\frac{3}{4}$  mile, and the area reclaimed was  $37\frac{1}{2}$  acres. The roadway was 100 feet wide from Westminster to Blackfriars Bridge and was continued all the way from thence to the Mansion House of a width of 70 feet. The cost of the embankment had been £1,200,000 besides £450,000 paid for the purchase of property. The tides now rose higher than in former years. On the 15th of November, 1875, the tide was 17 feet one inch, and in January, 1877 it was 16 feet 6 inches above datum. This had been attributed to the formation of the embankments; but it was ascertained that the cause was chiefly due to the removal of the old bridges and of other obstructions. This embankment was formed with a sewer and a

subway for gas and water pipes in the retaining wall. The subway was 7 feet 6 inches in height and 9 feet in width, and the sewer varied from 7 feet 9 inches to 8 feet 3 inches in diameter. The batter of the wall was slightly curved, and the wall was faced with granite, fine axed, up to high-water mark, and moulded above that level. There were steam-boat piers and landing places at various points. The Metropolitan District Railway had been constructed along the whole of this embankment, the level of the rails being  $17\frac{1}{2}$  feet below the surface of the roadway, which was supported by iron girders. The foundations of the embankment varied in depth with the nature of the ground, but were  $32\frac{1}{2}$  feet below Trinity high water. They were formed partly behind whole-tide timber dams driven into the clay as previously described by Mr. Ridley (Minutes of Proceedings of the Institution of Civil Engineers, vol. xxxi., page 3), and partly behind wrought-iron caissons, the caissons being used in bad ground, and near to the bridges and around the landing piers. The clay was reached at about 28 feet below Ordnance datum, but near Westminster bridge it was 32 feet deep. The level of the foreshore sloped from 6 feet above to 7 feet below datum. The foundations were carried down to 20 feet below datum; they rested mostly on the clay, and were formed of Portland cement concrete up to  $12\frac{1}{2}$  feet below datum, at which level the brickwork commenced. The bottom portions of the iron caisson coffer-dams were filled with concrete, and left in the ground permanently, and the piles of the wooden cofferdams were cut off under water at various levels, in both cases to protect the toe of the wall. The upper portions of the caissons were in half rings, and were capable of being used several times. When bolted together these rings formed an oval of 12 feet 6 inches in length by 7 feet wide in the center. The rings were 7 feet 6 inches deep, and were made of  $\frac{3}{4}$  inch and  $\frac{1}{2}$  inch wrought-iron plates. The lowest ring of each caisson was of cast iron, weighing about 32 cwt., and it had a cutting edge at the bottom. The caissons were bolted together longitudinally, and strips of felt rendered the joints watertight. These dams, like the timber dams, were supported by timber shoring from the land side, and the upper portions of the dams consisted of half caissons only, by which a considerable saving was effected. In each caisson there was a sluice, worked from the top, for admitting or discharging the tidal waters. The caissons were sunk by weighting them, and excavating within them by three methods: 1. By men working inside, the water being kept down by pumping; 2, by men working within, the water being excluded by pneumatic pressure; and 3, by a telescopic dredger, the water being allowed to rise and fall within the cylinders. By the first plan 6 cubic yards, by the second 5.31 cubic yards, and by the third ten cubic yards of material were excavated per diem. Again, according to the first system, a cylinder was sunk on an average in eight days and a third, and the labor cost 14s. 6d. per cubic yard. By the second, a cylinder was sunk 20 feet in eleven days and

a half, and the labor cost 12s. per cubic yard. By the third, a cylinder was sunk in less time at a cost of 8s. per cubic yard for labor.

The Albert Embankment was about 4300 feet long, and was similar in elevation to the Victoria Embankment. It had, however, neither sewer nor subway behind it. The foundations were carried to a depth of 30 feet below Trinity high water, and the wall was formed behind a whole tide timber dam, partly of single piles closely driven and caulked. Opposite Millbank the river had been widened for a length of 800 feet from 600 feet to 720 feet. Good foundations for this embankment were more easily reached than on the other side. Part of the embankment wall was formed of concrete instead of brickwork and the whole was faced with granite. The works cost £309,000.

The Chelsea Embankment was commenced in July, 1871 and completed May, 1874. It extended from Battersea Bridge to Chelsea Hospital, and was upwards of three quarters of a mile in length. The wall was composed of Portland cement concrete, faced with hammer dressed granite. It had a sewer from 5 feet 9 inches to 6 feet 9 inches in diameter behind it, conveying the sewage from Hammersmith to the Western Pumping Station. It had reduced the width of the river from 850 feet to 700 feet, and had reclaimed  $9\frac{1}{2}$  acres of foreshore. The roadway was 70 feet wide, and 5 feet above Trinity high water. The foundations were carried to 10 feet below Ordnance datum, or 4 feet under low-water spring tides, and they were put in behind a half tide dam. A trench was dredged and concrete blocks were bedded upon the ground at low water up to 3 feet 3 inches below datum. Above this level the concrete was filled in and bonded with the granite facing. The cost of this work, including the low-level sewer and roadway, was £134,000. The introduction of concrete in lieu of brickwork had effected a saving of of about £21,000. A short length of this embankment, opposite Cadogan Pier, settled in consequence of the removal of some piles, which formed part of the old pier, in front of it. The wall had since been underpinned from the land side, and its toe protected by sheet piling.

#### ORDNANCE AND NAVAL.

**STEEL SHIPS.**—On the 19th inst., a trial trip of a new steel vessel, the first built on the Tyne or elsewhere for ordinary sea going purposes, took place, and was completely successful. The vessel, which is named the Ethel, has been built by Messrs. C. Mitchell & Co., iron shipbuilders, Low Walker, to the order of Messrs. Henry Clapham & Co., merchants, Newcastle-upon-Tyne, and is intended for the Spanish ore trade. The length of the vessel is 210 feet between perpendiculars, and 216 feet over all; she is 30 feet beam, and 17 feet 3 inch depth moulded, or about  $16\frac{3}{8}$  depth of hold. She is guaranteed by the builders to carry 1,300 tons on 14 feet 7 inch draught of water. The hull of the vessel in iron was estimated to weigh 450 tons; the stem, stern post,

bed-plate of engines, etc., and engine room are of iron, and are estimated to weigh 90 tons, which, deducted from the figures above given, leaves the weight of the hull at 360 tons. For this steel has been substituted; and Lloyd's have allowed on the average about 20 per cent. off the scantling, showing a saving of about 73 tons in weight of the hull. This necessitated the providing of 73 tons extra water ballast, which has been effected by an arrangement in the engine room. The total water ballast is 250 tons. The class of the vessel is ninety-five years A1. The engines have been built by the Wallsend Slipway Company. Both ship and boilers are built of Landore-Siemens steel. As regards the boilers, Lloyd's have allowed 21 per cent. off the outer shell, and 10 per cent. off the weight of the internal parts. The boilers are fitted with weldless steel tubes. At these reductions of thickness the builders are confident that the vessel is stronger than if built in the ordinary way of iron. The material has shown an extraordinary toughness, and also great uniformity of quality. The breaking strain of the plates has been found, after very exhaustive tests, to be as follows:

No.	Elongation. Per cent.	Broke at tons to the square inch.
2.....	28 0.....	33
3.....	26.5.....	32½
4.....	26.5.....	32½
9.....	25.0.....	32½
10.....	28.4.....	32½
11.....	25.0.....	32½
	6)154.4	6)195¼
Average....	25.73	32½

The cost of the vessel has been about 8 per cent. more than if she had been built of iron. The other novelties introduced into the vessel are Sir Wm. Thomson's improved sounding machine, and Sir Wm. Thomson's improved mariners' compass. The chief objects aimed at in the latter are greater steadiness of the compass at sea in all weathers and in every class of ship; to reduce the fractional error to as small an amount as to cause no inaccuracy or inconvenience; to obtain greater security in the use of the compass in iron ships; and to diminish the expenses and annul the detentions at present required for adjusting compasses in iron ships. The sounding machine is designed for ascertaining accurately and quickly the depth of water under a ship, without stopping or even reducing her speed; and on test proved accurate to half a fathom in nineteen.—*Engineering.*

### BOOK NOTICES.

INDEX CATALOGUE OF BOOKS AND MEMOIRS RELATING TO NEBULÆ, CLUSTERS, ETC. By EDWARD S. HOLDEN. Washington: Smithsonian Institute.

Indispensable to practical observers who work in this field. The catalogue contains 110 pages closely printed.

THE MONTHLY WEATHER REPORTS for March and April have come to hand since our last issue. The recent extension of the service of this department to include the Pacific coast, gives a new interest to the monthly issues. We believe no records of scientific labor are studied so closely or profitably, nor with so much of national pride, as those of the Weather Bureau.

SECOND ANNUAL REPORT OF THE STATE SURVEY, 1878.

The report of the Commissioners is a brief statement of the work performed in 1877. The report of the Director, Mr. James T. Gardner, is appended, including two maps, indicating the recent progress of the work. The maps are somewhat rudely executed, but exhibit some important corrections to be made in the old maps.

PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS. London: printed by Wm. Clowes & Sons.

The following papers in separate pamphlets, have been lately received from Mr. James Forrest, Secretary of the Institution.

The works of the Bilbao Iron-Ore Company in the Province of Biscay, Spain. By Frederick Cadogan Barron, A. I. C. E.

Irrigation in the South of France. By George Wilson, M. I. C. E.

Progress of Steam Shipping during the last quarter of a century. By Alfred Holt, M.I.C.E.

The Encroachments of the Sea from Spurn Point to Flamboro Head. By Robert Pickwell, A. I. C. E.

As each of the above papers relates to an important branch of engineering, the value of these additions to scientific literature, emanating from such high sources, is not easily overstated.

ACADIAN GEOLOGY. The Geological Structure, Organic Remains, and Mineral Resources of Nova Scotia, New Brunswick, and Prince Edward Island. Third edition; with a Geological Map and numerous Illustrations. By J. W. DAWSON, F.R.S., F.G.S., Principal of McGill College. Pp. 818; royal 8vo, Cloth, \$6.00. Montreal: Dawson Brothers. For sale by D. Van Nostrand. Price of Supplement, \$1.25.

This third edition of Dr. Dawson's important work is brought down to the most recent date by a Supplement containing all that has been discovered or established, since the publication of the second edition, concerning the Geological Structure; Fossil Remains and Mineral Resources of the Eastern Provinces. The work from the extent of its scope and the fullness of its detail is absolutely necessary to every one who may be interested in the development of the resources of these Provinces. The map is colored geologically, and there are besides in the book over 400 illustrations. The labors of a life time of scientific research have been expended upon the elucidation of the Geology of these most interesting Provinces, and the results have been embodied by Principal Dawson in this handsome volume now reaching to 818 pages of octavo. The Supplement may be had separately by purchasers of the previous edition.

**HOUSE DRAINAGE AND WATER SERVICE.**  
By JAMES C. BAYLES. New York: David Williams. For sale by D. Van Nostrand. Price \$3.00.

The author of this valuable and opportune work, modestly says of it, that "it is only just to the professional reader to say that this book is not intended as a contribution to the literature of sanitary engineering. It takes up the subjects of drainage and water supply where the engineer commonly leaves them, and treats almost exclusively of subjects in which householders and those connected with the house-building trades, are directly and immediately interested."

We may add that all intelligent readers will regard the treatise as an indispensable supplement to the best works on sanitary engineering. It deserves, and we trust will receive a welcome from the large constituency who believe in modern sanitary reform in the dwelling house.

**PROF. ROBERT H. THURSTON'S SCIENTIFIC ESSAYS.**

On a new type of steam engine, theoretically capable of utilizing the full mechanical equivalent of heat-energy, and on some points in theory indicating its practicability. Reprinted from Franklin Institute Journal.

On a new method of Planning Researches, and of representing to the eye the results of combination of three or more elements in varying proportions.

A paper presented to the American association for the advancement of science. Salem: Printed at the Salem Press.

Abstract of the statement of the extent and character of the work of the United States Board appointed to test iron, steel, and other metals. From the papers of the American Association.

The Growth of the Steam Engine, New York: D. Appleton & Co.

All of Prof. Thurston's papers are concise and accurate, and whether historical or otherwise, always relate to the present needs of engineering science.

**WORKS ON FOREST SCIENCE BY DR. BROWN.**

**HYDROLOGY OF SOUTH AFRICA ;** or Details of the former hydrographic condition of the Cape of Good Hope, and of causes of its present aridity, with suggestions of appropriate remedies for this aridity.

In which the desiccation of South Africa, from pre-Adamic times to the present day, is traced by indications supplied by geological formations, by the physical geography or general contour of the country, and by aborescent productions in the interior, with results confirmatory of the opinion that the appropriate remedies are irrigation, arboriculture, and an improved forest economy : or the erection of dams to prevent the escape of a portion of the rainfall to the sea—the abandonment or restriction of the burning of the herbage and bush in connection with pastoral and agricultural operations—the conservation and extension of existing forests—and the adoption of measures similar to the *reboisement* and *gazonnement* carried out in France, with a view to prevent

the formation of torrents and the destruction of property occasioned by them.

**REBOISEMENT IN FRANCE ;** or Records of the re-planting of the Alps, the Cevennes, and the Pyrenees with trees, herbage, and bush, with a view to arresting and preventing the destructive consequences of torrents.

In which are given, a *resume* of Surret's study of Alpine torrents, and of the literature of France relative to Alpine torrents, and remedial measures which have been proposed for adoption to prevent the disastrous consequences following from them—translations of documents and enactments, showing what legislative and executive measures have been taken by the Government of France in connection with *reboisement* as a remedial application against destructive torrents—and details in regard to the past, present, and prospective aspects of the work.

**FORESTS AND MOISTURE.** Effects of forests on humidity of climate.

In which are given details of phenomena of vegetation on which the meteorological effects of forests affecting the humidity of climate depend—of the effects of forests on the humidity of the atmosphere, on the humidity of the ground, on marshes, on the moisture of a wide expanse of country, on the local rainfall, and on rivers—and of the correspondence between the distribution of the rainfall and of forests—the measure of correspondence between the distribution of the rainfall and that of forests—the distribution of the rainfall dependent on geographical position, determined by the contour of a country—the distribution of forests affected by the distribution of the rainfall—and the local effects of forests on the distribution of the rainfall within the forest district.

**THE SCHOOLS OF FORESTRY IN EUROPE.** A plea for the creation of a School of Forestry in Edinburgh.

**WATER SUPPLY OF SOUTH AFRICA,** and facilities for the storage of it.

*Ready for the Press.*

**ARBORICULTURE IN SOUTH AFRICA ;** or Facilities for the planting of trees existing in different districts at the Cape of Good Hope, with reports on the natural history, culture, and exploitation of the trees which have been recommended for culture in the colony.

*Preparing for the Press.*

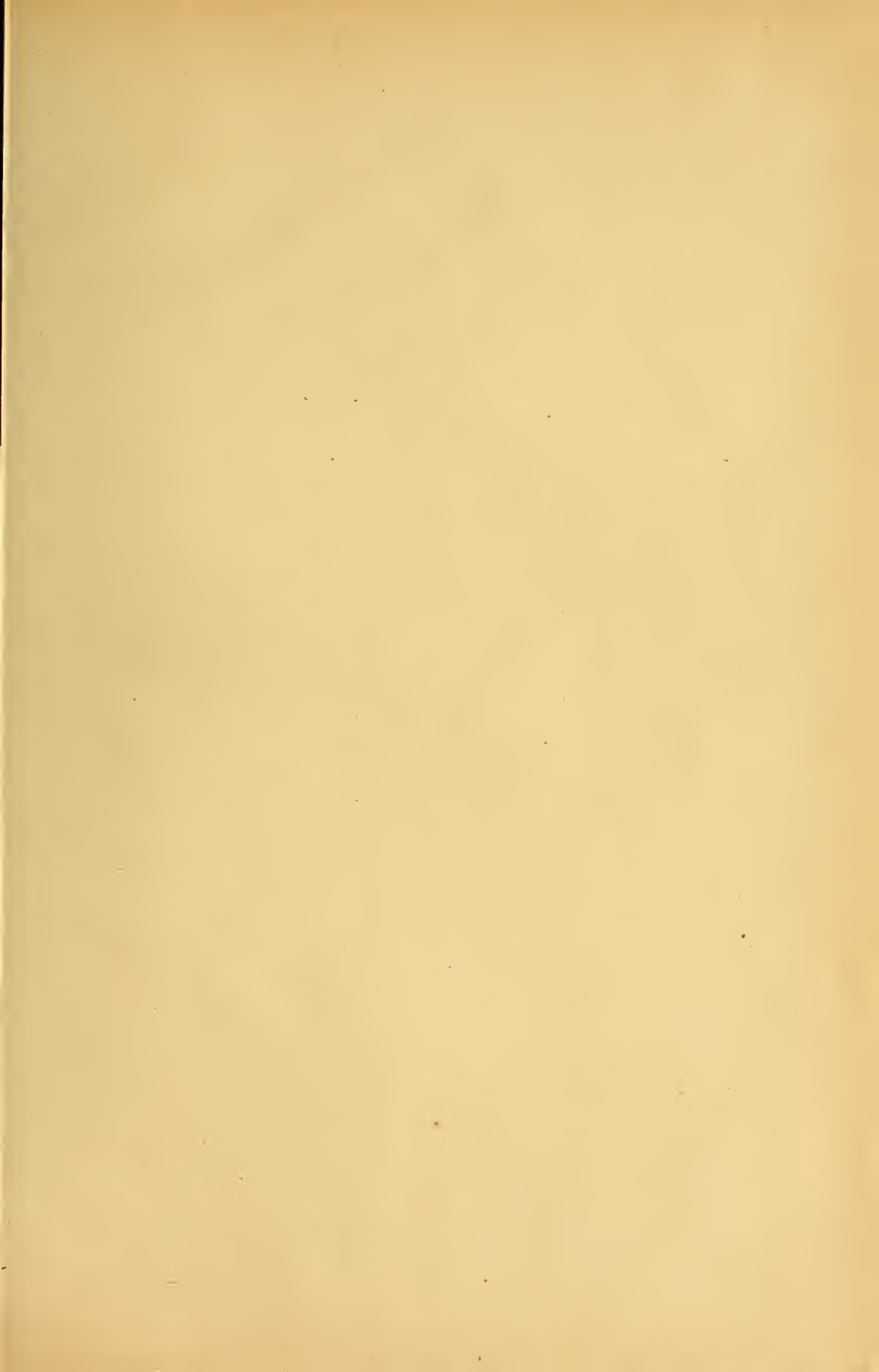
**DRIFT SANDS.** Report on the arrest of drift sands and the utilization of sand plains by silviculture in France, Belgium, Germany, Russia, Hungary, and other lands, with a view to showing the practicability of arresting and utilizing drift sands and sand plains in South Africa.

## MISCELLANEOUS.

**THE** revenue of the Suez Canal Company in 1877 amounted to £1,310,456. The corresponding revenue in 1876 was £1,198,999 ; and in 1875, £1,135,452. The company's revenue thus increased at a more rapid rate in 1877 than in 1876, notwithstanding that a reduction of 5d. per ton was made in the tolls in April, 1877.











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